"An invasion of armies can be resisted, but not an idea whose time has come."

Victor Hugo
Les Miserables

Advancing Asset Management in Your Utility: A "Hands-on" Approach

Day 1

AGENDA

Day 1

- *Welcome, Introductions & Housekeeping Details*
- *"Storyline" Introduction, Background And Context*
- *Overview Of Fundamental Concepts & Core Practices*
- *The Storyline: Tom's Really Bad Day*
- *Core Question 1: What Is The Current State Of My Assets?*
- *Core Question 2: What Is My Required "Sustainable" Level Of Service?*
- *Core Question 3: Which Assets Are Critical To Sustained Performance?*
- *Review of Key Slides; Discussion / Q & A*

Day 2

- *Summary of Day 1; Outline of Day 2*
- *Core Question 4: What Are My Minimum "Life-cycle-cost" CIP and O&M Strategies?*
- *Core Question 5: Given The Above, What Is My Best Long-term Funding Strategy?*
- *Focus Topic 1: Deploying An AAM Program*
- *Focus Topic 2: Meeting The IT Challenge – Toward An Enterprise Asset Management System (EAMS)*
- *Summary, Addressing Your Questions, Comments*

Who is GHD LLC?

World's Best Practices

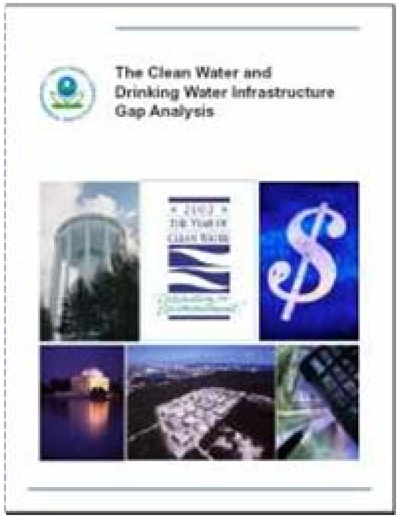
- Australian-based international company of 4200+ management consultants, engineers, scientists, planners, architects
- Recognized as a world leader in advanced asset management
- Literally, "wrote the book" on Best Practices
- Hundreds of engagements over two decades
- Faculty for USEPA's national Asset Management Training Workshops

"Side-by-side" Mentoring

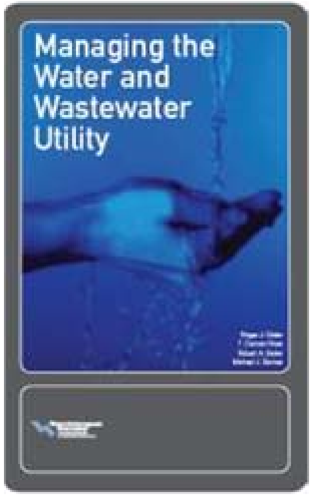
AM Knowledge Management

Our "Faculty"

Mr. Steve Allbee - *USEPA Project Director, Gap Analysis; primary author, USEPA's <u>The Clean Water and Drinking Water Infrastructure Gap Analysis</u>; 26 years EPA - development of financing programs; BA, MA, MPA.*



Mr. Duncan Rose - *VP, Service Group Manager – GHD USA; Former city/county manager; co-author of WEF's <u>Managing the Water & Wastewater Utility</u>; 30 years state & local management; Adjunct Faculty, Florida State University, Askew School of Public Policy and Administration; BA, MSP, MAPA.*



Mr. Doug Stewart, P.E. – *Principal Consultant, GHD; former Asset Management Program Director, Orange County Sanitation District; 25 years engineering experience, 10 years utility management; BS, MSCE.*

Mr. Philip Tiewater, P.E. - *Principal Consultant and Deputy Service Group Manager - East, GHD; Former Public Works Director; 25 years municipal engineering experience; BA, MPA.*

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Bottom Line: Emergent Industry Profile

- Increasing aggregate demand – water and wastewater
- Diminishing available water resources
- Leveling of "production efficiencies"
- Increasing output restrictions
- Aging infrastructure
- ➢ ***Result: Increasingly expensive treatment options***

- Aging customer base – more and more on fixed income
- Diminishing technical labor pool running larger and more sophisticated plants and facilities
- Outflow of knowledge with retiring labor base
- Increasing resistance to rate increases
- ↘ ***Result: Increasingly complex management environment***

The Changing Utility Business Environment

- Demands to do more with what we have got
- Need to better focus our capital & operating budgets
- Move from reactive based activities to a greater planned and predictive work environment
- Transition from being really good at *building and operating* assets to being really good at *managing* assets:
  - Extending asset life and achieving acceptable reliability
  - Optimizing maintenance, renewal
  - Developing accurate long term funding models

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The Consequences of Asset Failures Can Be Severe

Management Engineering Environment GHD Clients People Performance

Advanced Asset Management helps make…

better acquisition, operations, maintenance, and renewal and replacement DECISIONS

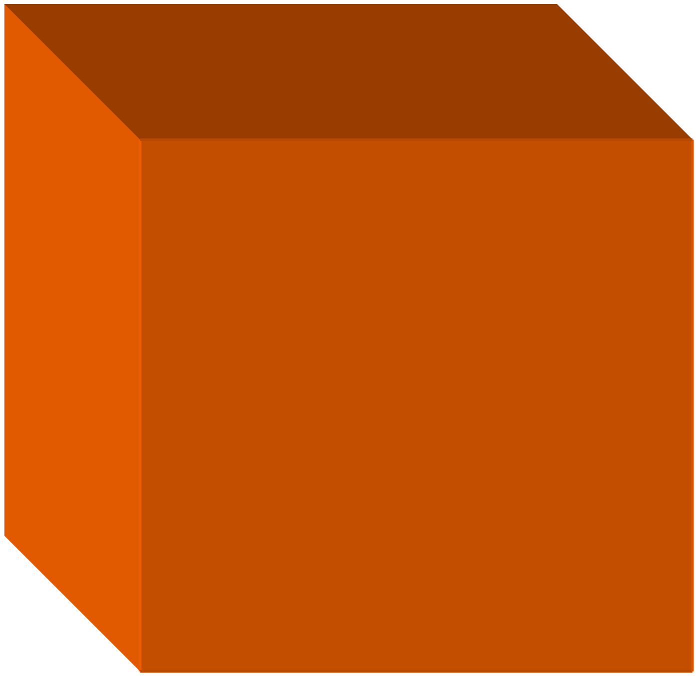
By the end of this workshop you should be able to address these five questions:

What is AM?	Why do AM?	What "deliverables" do I get?	How to do it?	How do I move forward?

Management Engineering Environment GHD Clients People Performance

Building the "AM MetaBox"

- Definition
- Life cycle
- Four "conceptual framework" views of Asset Management
- Charter Principles
- An Asset Management Plan



“Meta” View 1: Our “Fancy” Definition of AM

Advanced Asset Management (“AAM”) is

- a management paradigm and a body of management and human practices
- that is applied to the entire portfolio of infrastructure assets at all levels of the organization
- that seeks to minimize the total cost of acquiring, operating, maintaining and renewing the assets
- within an environment of limited resources
- while continuously delivering the service levels customers desire and regulators require
- In a cultural environment that encourages maximum development and satisfaction of our human assets.

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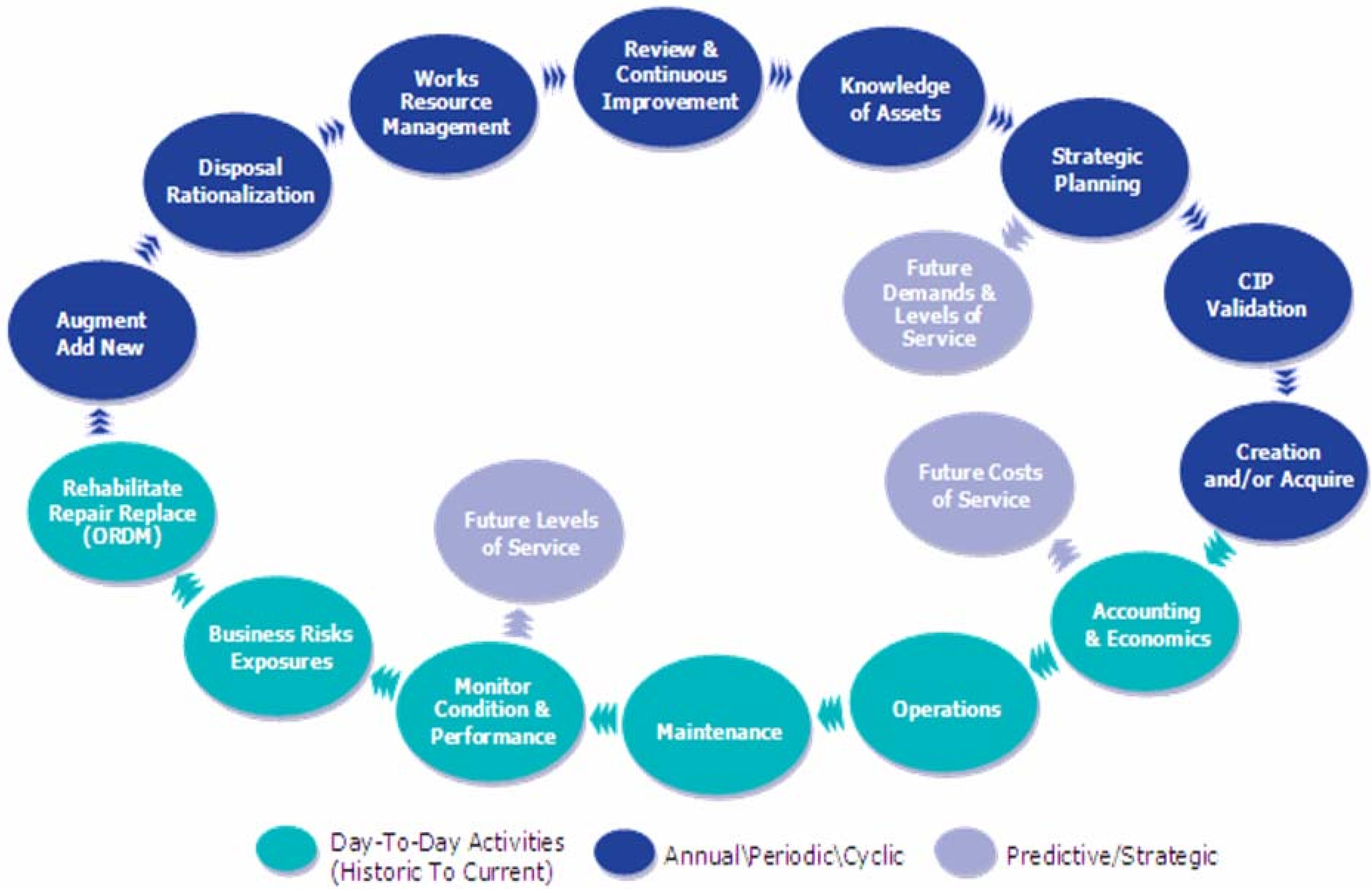
“Meta” View 2: The Asset Life Cycle

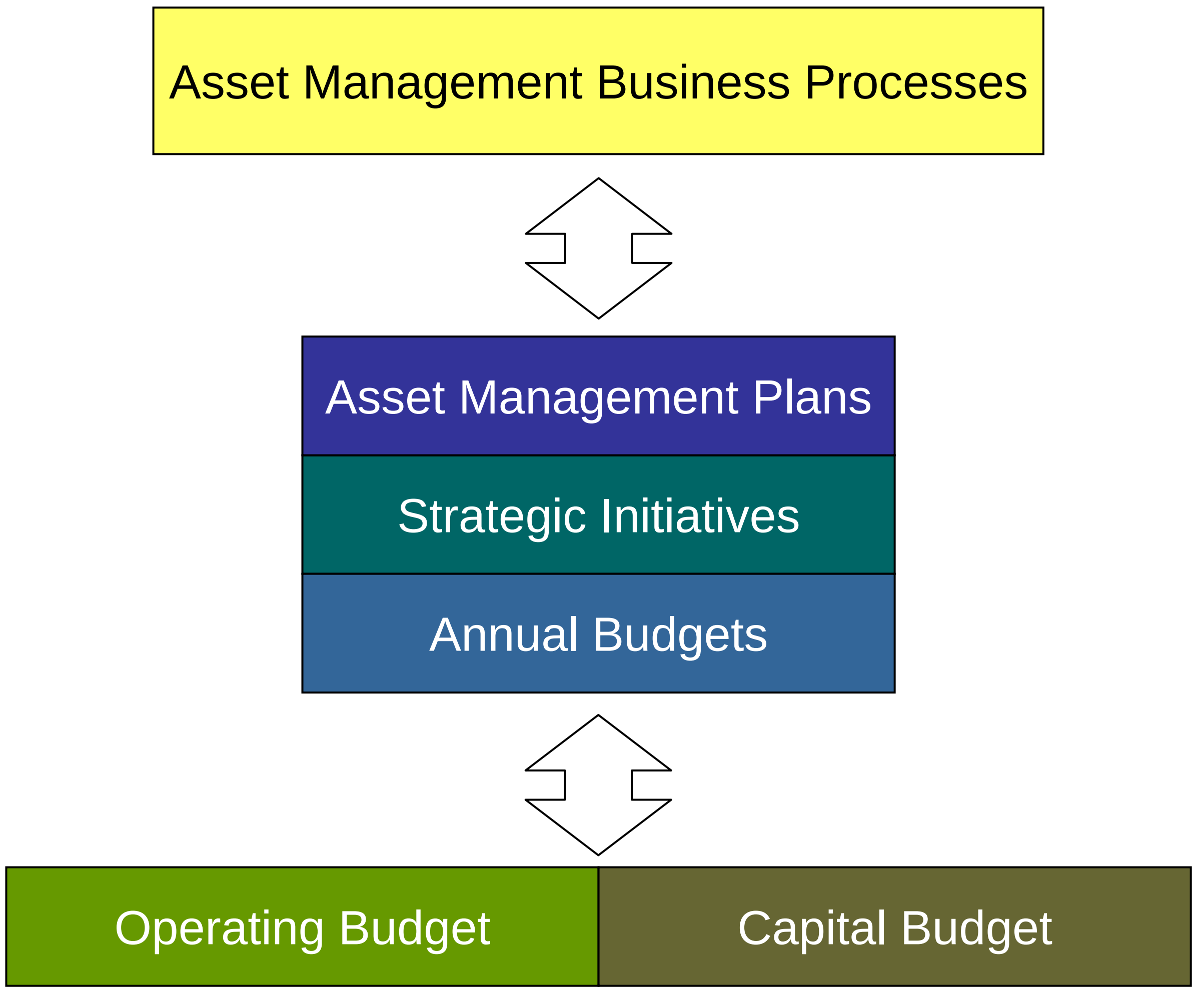


“Meta” Views 3 – 6: Four Different Perspectives of “Asset Management”

- The “Quality Elements” View
- The “Management Framework” View
- The “5 Core Management Questions” View
- The “Core Processes and Practices” View

“Meta” View 3: The “Quality Elements” View

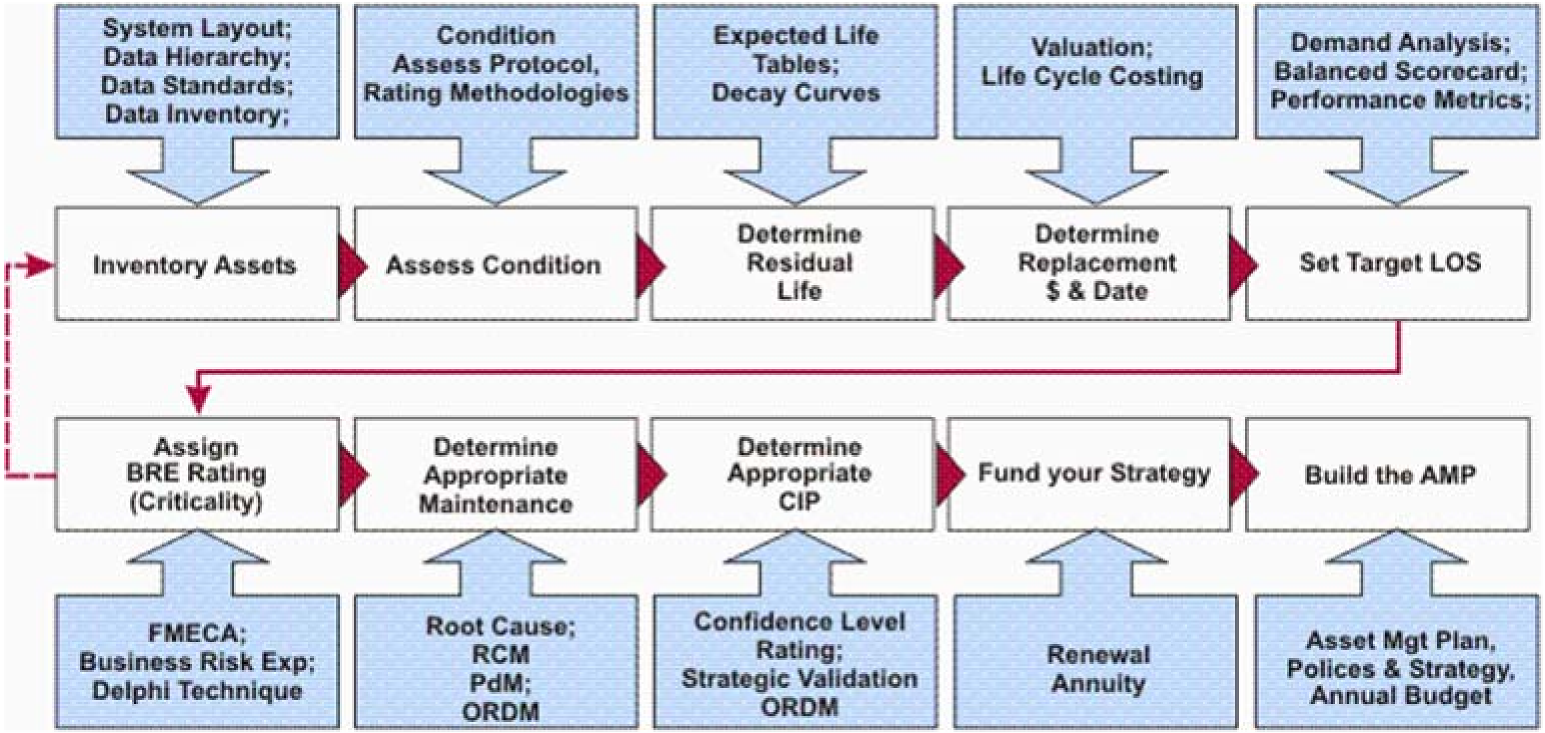
“Meta” View 4: The “Management Framework” Perspective



“Meta” View 5: The “5 Core Questions” View

Core Questions
1. What is the current state of my assets? • What do I own? • Where is it? • What condition is it in? • What is its remaining useful life? • What is its economic value?
2. What is my required sustained Level Of Service? • What is the demand for my services by my stakeholders? • What do regulators require? • What is my actual performance?
3. Given my system, which assets are critical to sustained performance? • How does it fail? How can it fail? • What is the likelihood of failure? • What does it cost to repair? • What are the consequences of failure?
4. What are my best “minimum life-cycle-cost” CIP and O&M strategies? • What alternative management options exist? • Which are most feasible for my organization?
5. Given the above, what is my best long-term funding strategy?

"Meta" View 6: The "Core Processes and Practices" View



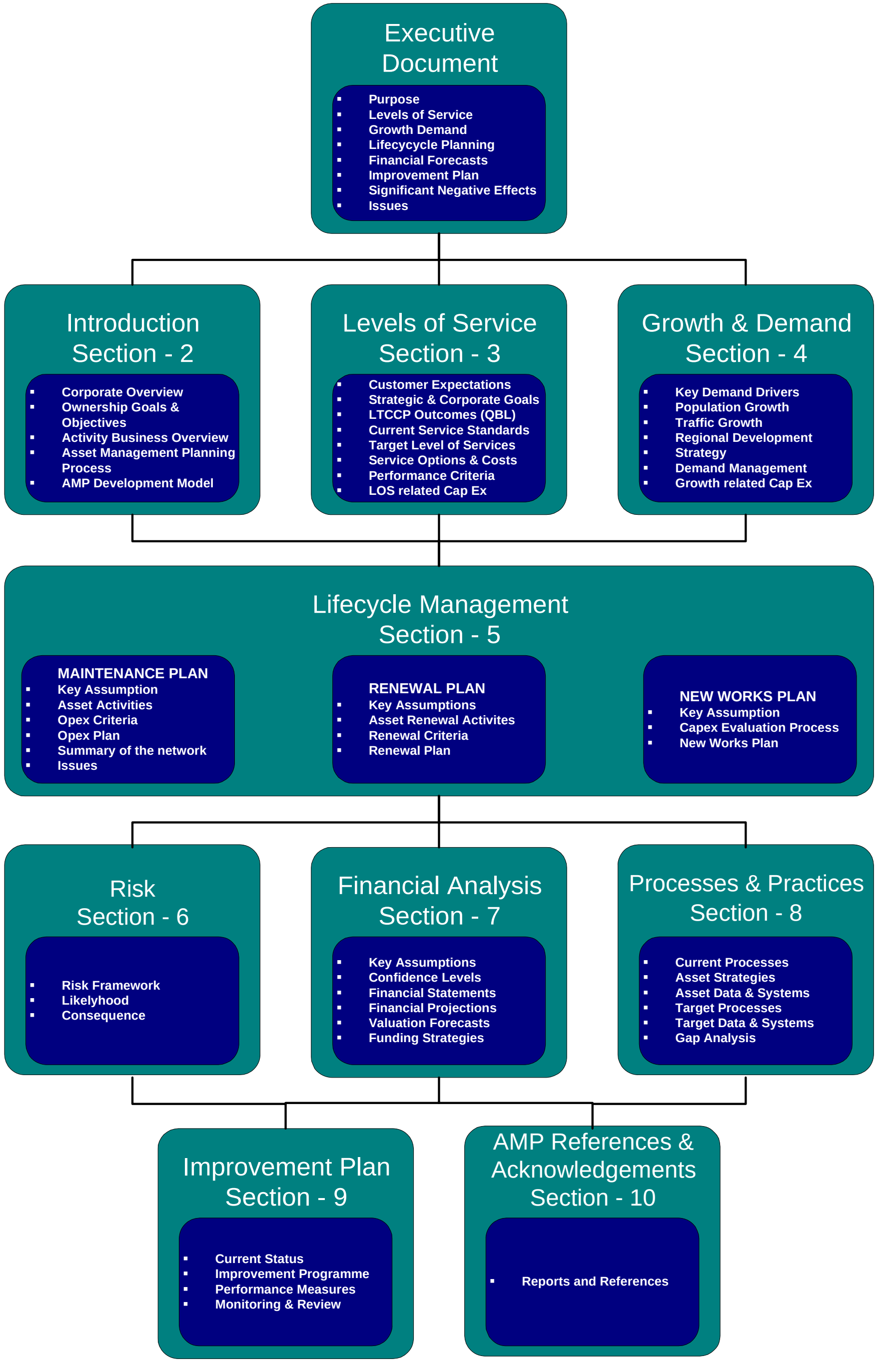
“Meta” View 7: Charter Principles

GHD

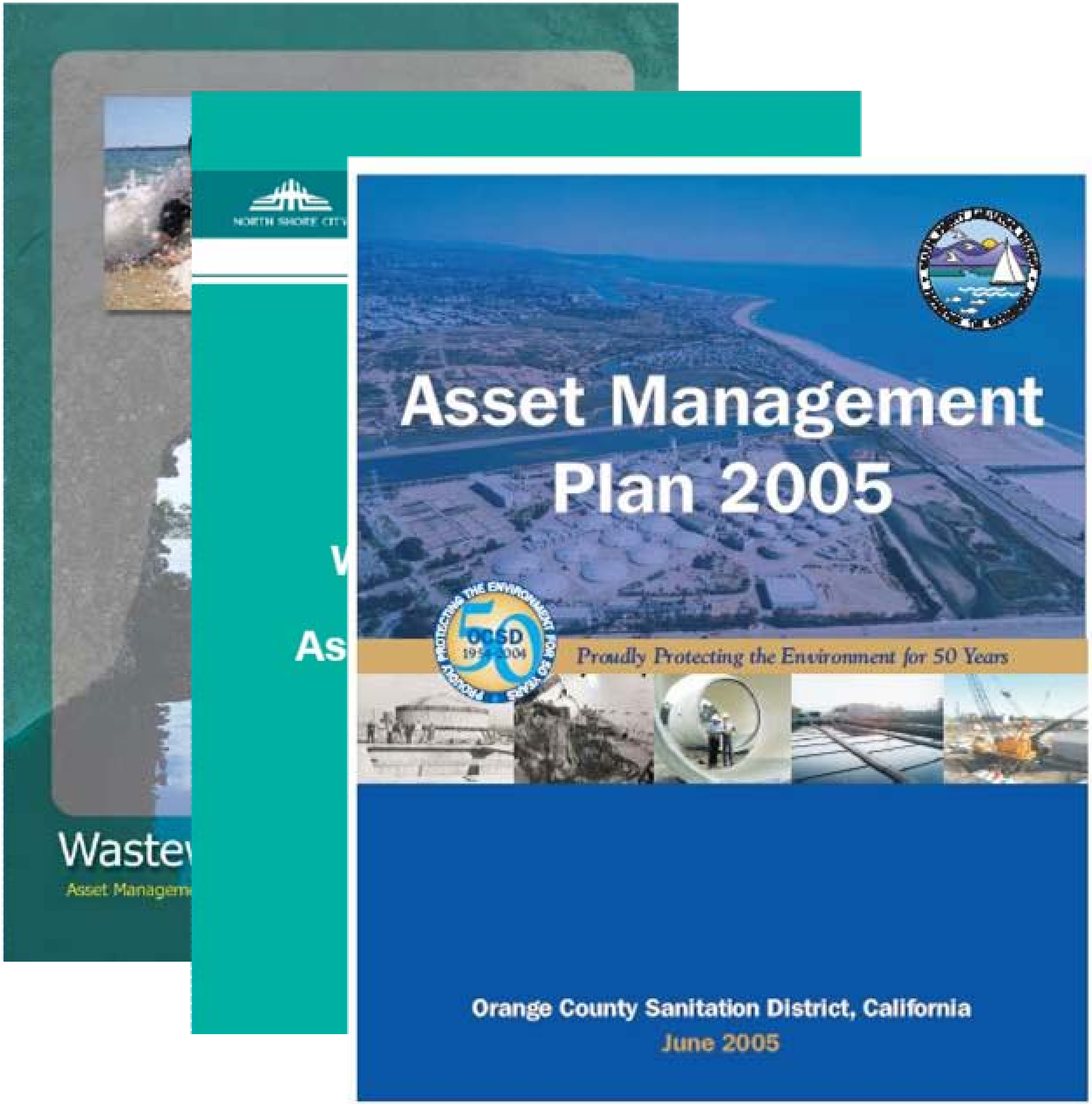
Over-Arching TEAM* Principles

- **Asset Inventory.** We will know the assets that we own, or for which we have legal responsibility, and will maintain an accurate computerized asset register developed around an asset hierarchy that supports advanced asset management functions.
- **Condition Assessment.** We will gather, record, and analyze condition assessment data; store and analyze it using user friendly computerized systems; design these systems to support high confidence level asset related decision making; and create a comprehensive and dynamic condition index.
- **Maintenance.** We will retain a detailed maintenance policy, and operate a user friendly, accurate, and comprehensive enterprise asset management system (that includes a Computerized Maintenance Management System) to ensure that the assets, facilities, and systems perform to their design criteria and meet their design lives.
- **Information Technologies and Analysis and Evaluation.** We will store and analyze our data and knowledge in integrated or interconnected, user friendly, efficient, and effective computerized business information systems that support our total organization and our TEAM Program responsibilities, vision, and goals.
- **Levels of Service (LOS).** We will thoroughly understand and record our current levels of service, including customer service elements, and will report our performance in meeting these in annual asset management plans. These plans will include service level options and costs, and likely future LOS requirements necessary for sustained performance. We will assess the indirect or ancillary cost impacts of inadequate asset condition or performance on our customers and the community in terms of the economic consequences of failing to meet our established levels of service.
- **Financial Planning.** We will understand the value and costs of our assets and the financial resources needed to appropriately sustain them (short and long term). We will make our decisions based on Total Life Cycle costs, and will have appropriate pricing and funding strategies that match our business needs and targeted levels of service. We will measure and report full economic costs of our activities and apply them to the relevant service. We will link the condition index to our customer's expectations, financial capacity, and our levels of service goals.
- **CIP and Annual Budget Funding Processes and Procedures.** We will have uniform processes across our whole organization for the evaluation of our investments in capital projects, maintenance, or operations. These processes will include risk and benefit costs, impact on levels of service, and asset management decision making quality confidence levels. We will make our funding decisions about individual projects when all service programs within the business have completed their capital and annual operating budgets, and the impacts of our decisions on levels of service, asset and service sustainability, and rates are known. We will link our organizational goals to our investments and ultimate action plans.
- **Capital Improvement Planning.** We will only approve capital for new assets or services with an understanding and commitment to the recurrent O&M funding necessary to sustain them. We will plan our infrastructure asset investments to meet current and forecasted demands within the expected life of the assets.
- **TEAM Reporting.** We will report our overall performance in financial, social, environmental, and technical terms in an annual total enterprise asset management report.
- **TEAM Risk Management.** We will monitor, understand, and manage the risks involved in our business activities and ensure that our policies, processes, and practices reflect this commitment.
- **TEAM Program Management.** We agree that to do life cycle asset management efficiently and effectively, we need to apply Best Appropriate Life Cycle Processes and Practices to our valuable community assets, acquire and maintain the necessary data and knowledge needed for these processes, store this data and knowledge in the most appropriate Asset Management Information Systems (AMIS), and prepare an Asset Management Plan so that the strategy is consistent with appropriate law, for services provided.
- **TEAM Program Best Appropriate Practices.** We believe that only when we can confidently claim that all of the above facets of TEAM are in use, will Best Appropriate Practices (BAP) in TEAM have been achieved for the benefit of our OCSD customers and stakeholders.

TEAM – Total Enterprise Asset Management



"Meta" View 8: The Enterprise Asset Management Plan



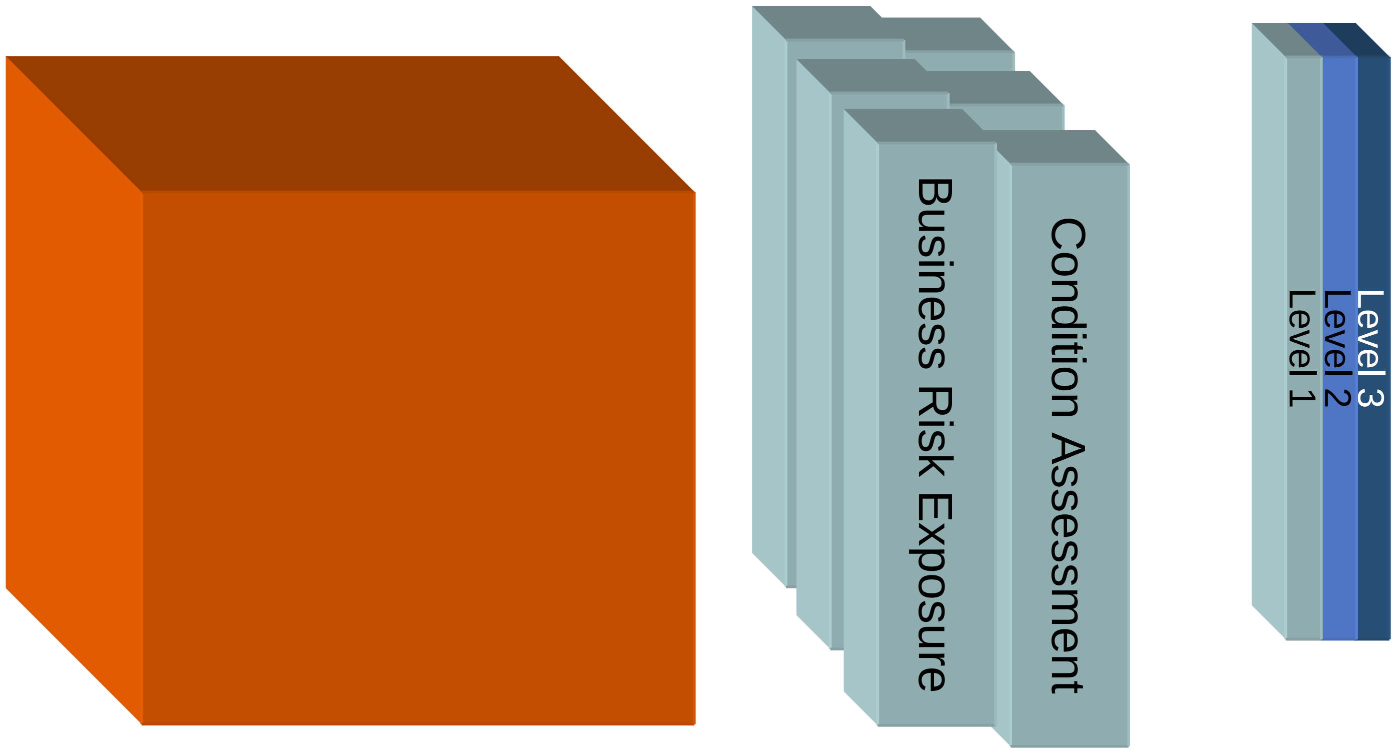
The Total Asset Management Plan

Example: Organizational AM Strategies

Strategy	Objective/ Description	Related Service Standard
Strategic Planning		
M.1 Organisational Structure	**Manage the wastewater system through a structure that maintains a separation between asset management and service delivery to promote accountability, transparency and efficiency** Asset management staff will be responsible for ensuring the Council achieves its objectives for wastewater services through setting, implementing, and monitoring of strategy and process. The actual delivery of wastewater services will be contracted, through competitive market mechanisms, to various service providers, who are concerned with the way the assets are operated and maintained in order to meet defined service standards.	Value for money Financial management Maintain service potential of assets
M.2 Human Resources	**Develop the professional skills of the staff through adequate training and experience.** Training needs will be agreed with staff each year at performance reviews and a register maintained to record training history. Staff are encouraged to belong to appropriate professional bodies and to attend appropriate conferences, seminars and training courses	Value for money
M.3 AM Plan Updates	**The Asset Management Plans remain strategic 'living' documents and will be reviewed on a regular basis.** The scope of the review will be influenced by changes in service standards, improved knowledge of assets, introduction of AM improvements and corporate strategy/ policy and process. The Wastewater Asset Manager, Policy Advisor and other senior management members will be involved in the plan review pro[illegible]	Legislative standards
M.4 Risk Management	**Manage risk exposure by completing an annual [illegible] assessment to update the Wastewater Ri[illegible] and implement risk mitigation m[illegible] exposure at a level comp[illegible]** Risk mitigation m[illegible] [illegible]opriate insuran[illegible] [illegible]g, condition monitoring [illegible] [illegible]ance, use of telemetry, [illegible] quality plan and operations manuals, [illegible] physical works programmes.	[illegible] standards Financial standards Legislative standards
[illegible]	**[illegible] services will continuously review service standards [illegible]monitoring customer feedback and applying appropriate consultative methods.** Consultative mechanisms will include the Code of Service, customer surveys and Customer Call Centre processes.	Service continuity Customer contact Service standards Legislative compliance

Strategy without action is merely a dream!

Inside the AM Metabox



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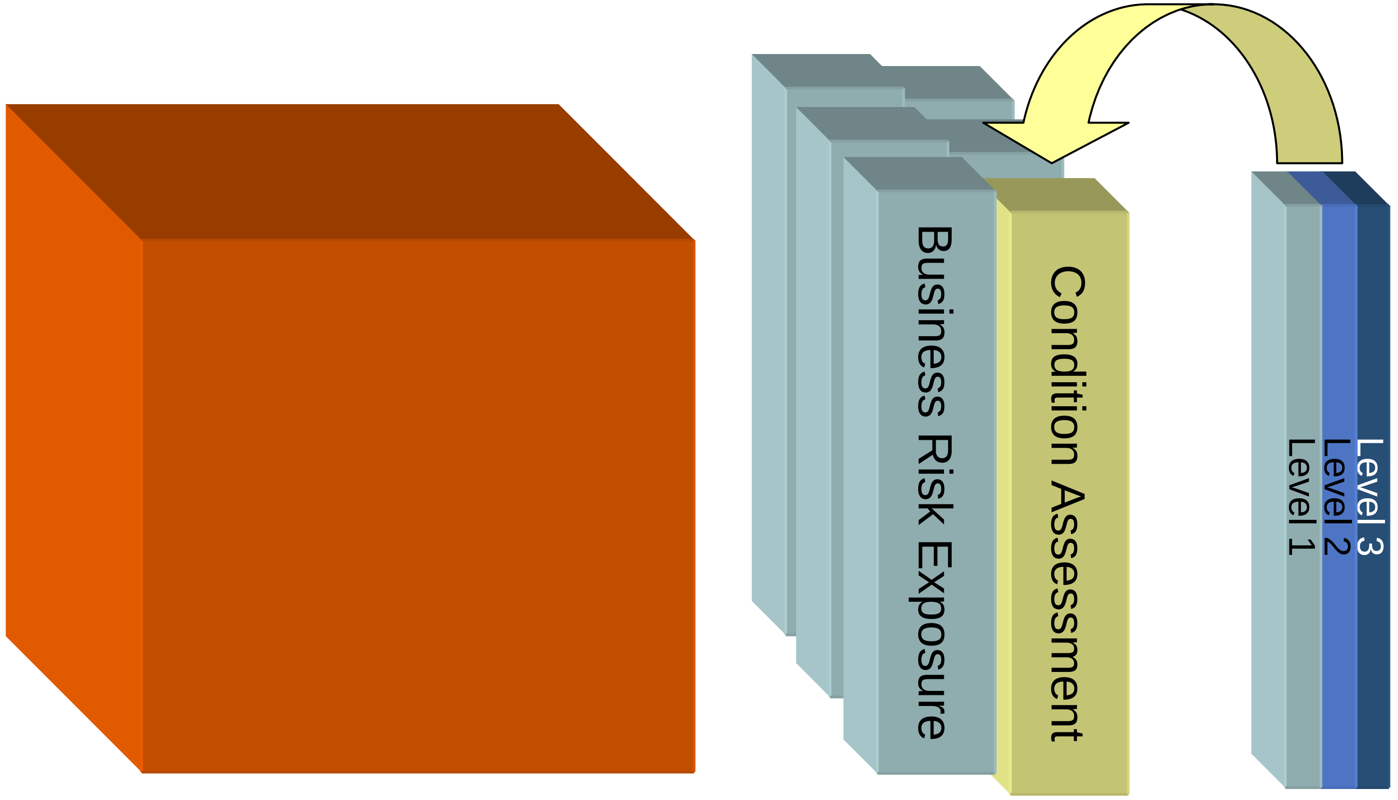

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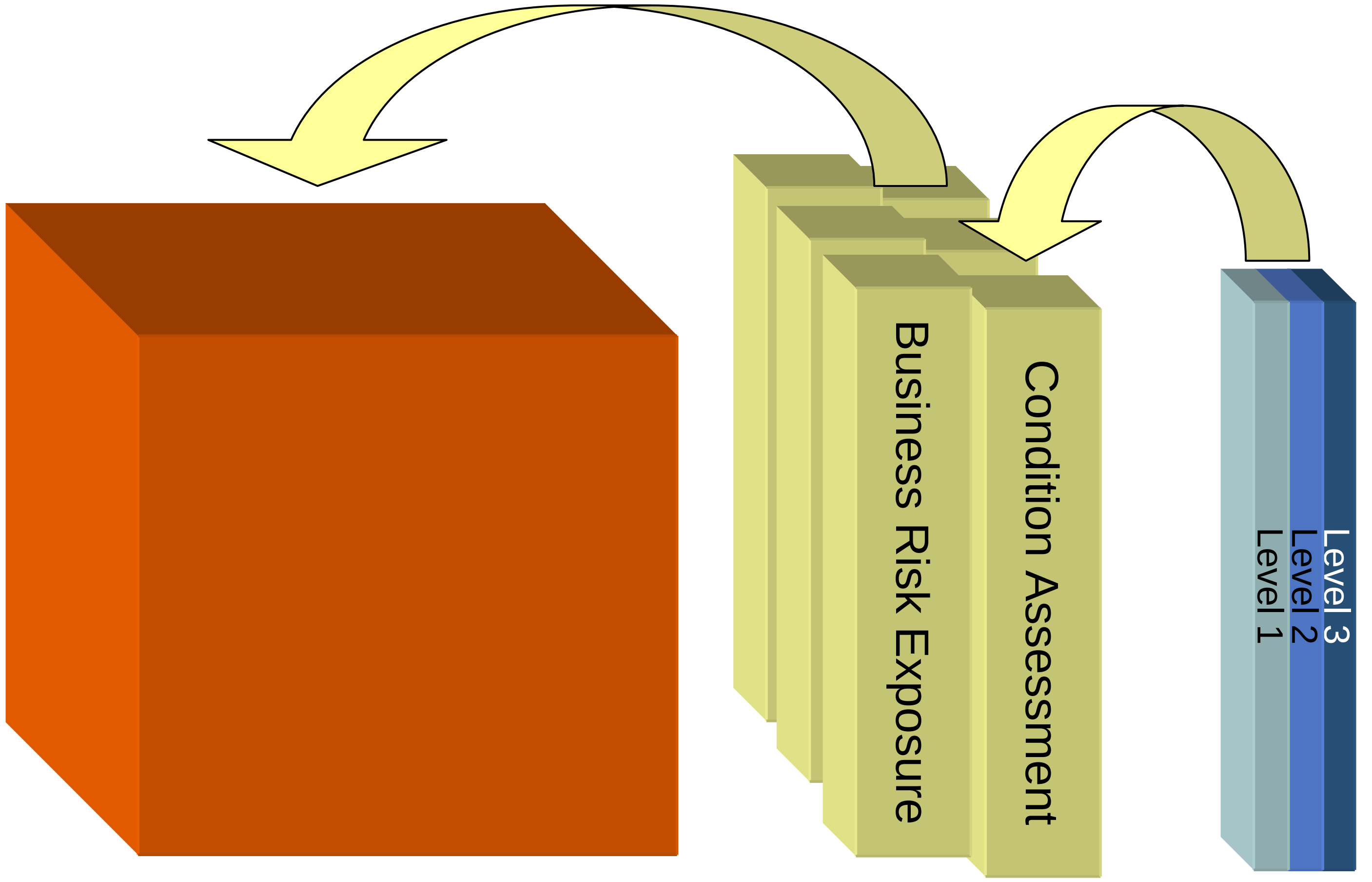
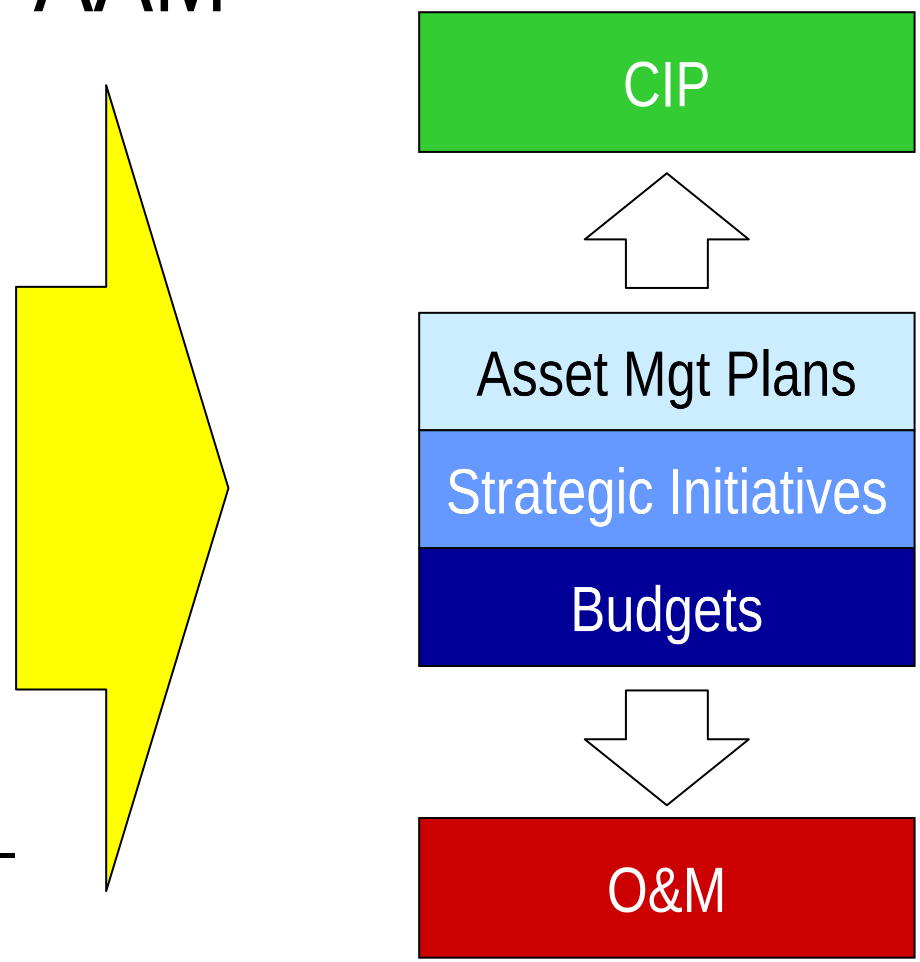
Inside the AM Metabox



The Nine Fundamental "Building Blocks" of AAM

1. Definition
2. The asset life-cycle
3. How assets fail
4. Risk-consequence
5. Cost/valuation
6. Asset demand
7. Level of service
8. Business risk
9. Confidence in decision-making



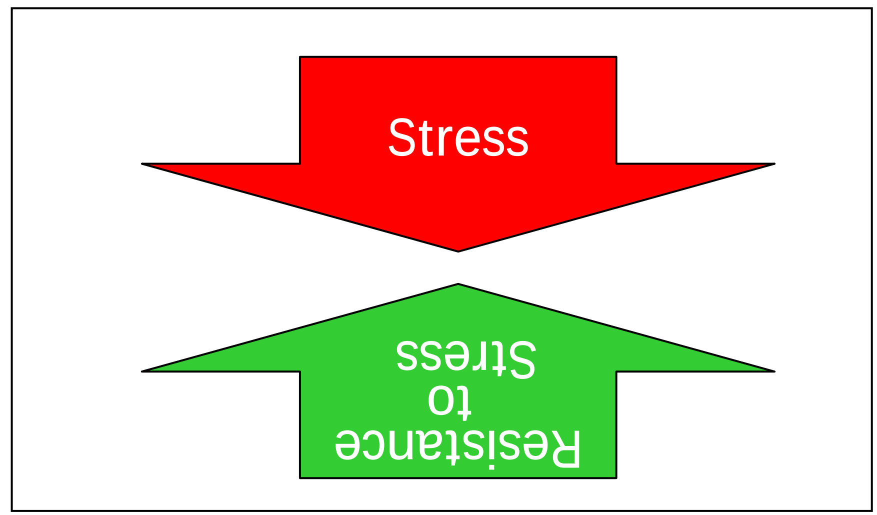
This Workshop Focuses on Three Fundamental Management Decisions:

- What are my work crews doing and where are they doing it – AND WHY!!?
- What CIP projects should be done and when?
- When to repair, when to rehab and when to replace?

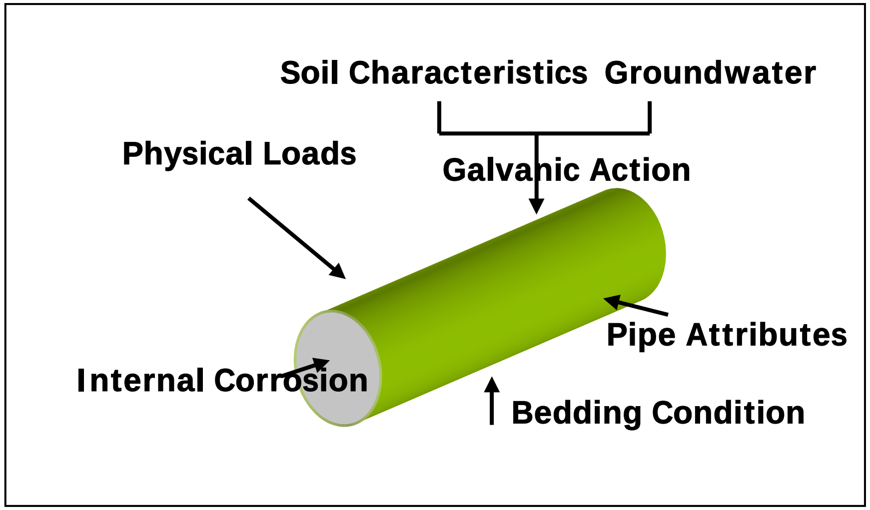
These decisions typically account for at least 80% of a Utility's annual expenditures!

Key to Sustainability – Understanding How Our Assets Fail

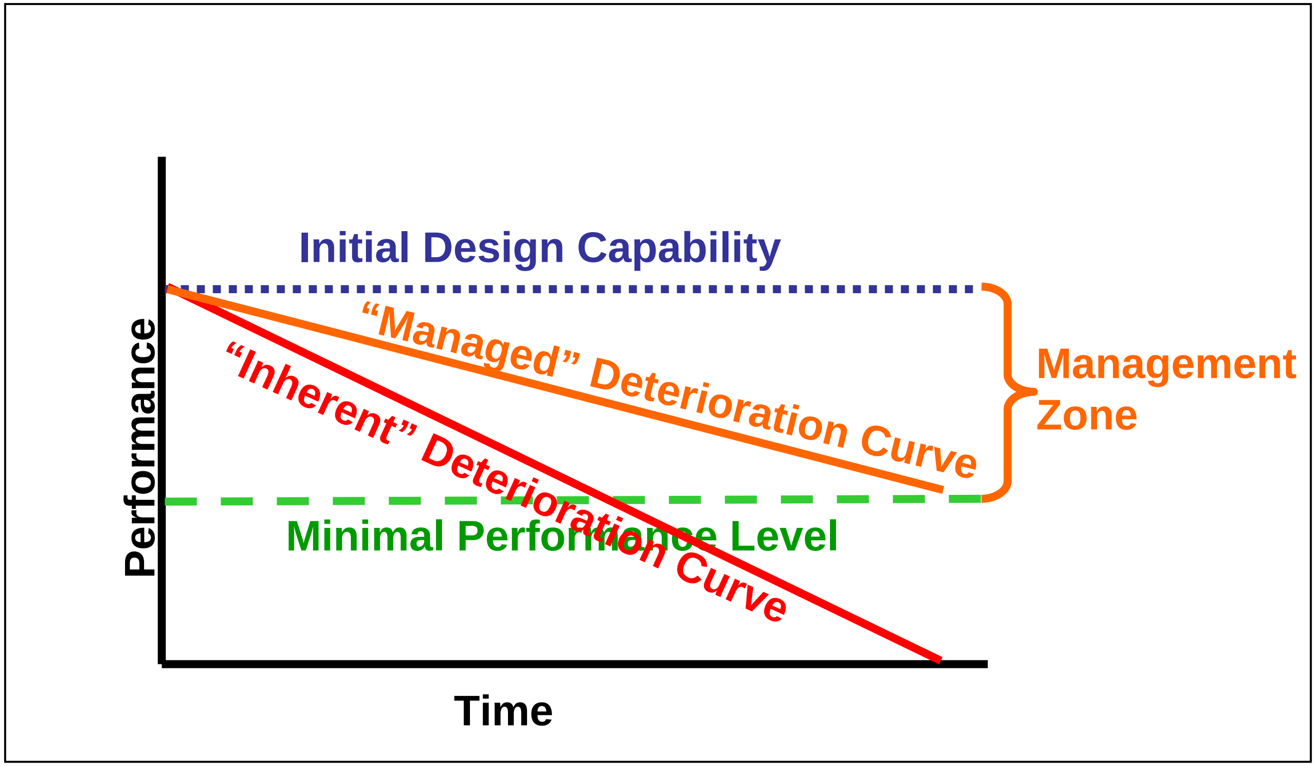
The yin-yang of asset failure



Key to Sustainability – Understanding How Our Assets Fail



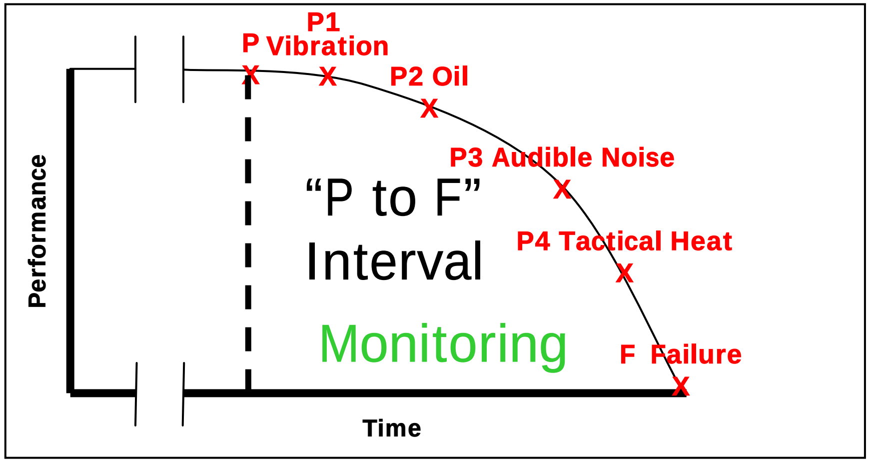
Key to Sustainable Performance – Understanding How Our Assets Fail



“Failure is defined as the inability of any asset to do what its users want it to do.”

John Moubray

Key to Sustainability – Understanding How Our Assets Fail

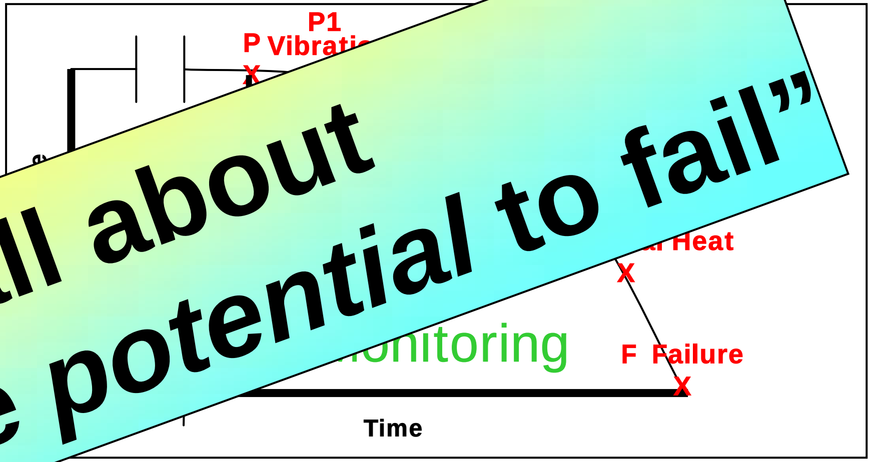


Key to Sustainability – Understanding How Our Assets Fail

Findings:

- Only a moderate relationship between *preventive* maintenan... an...

...e is ...*irected!*



AM is all about "managing the potential to fail"

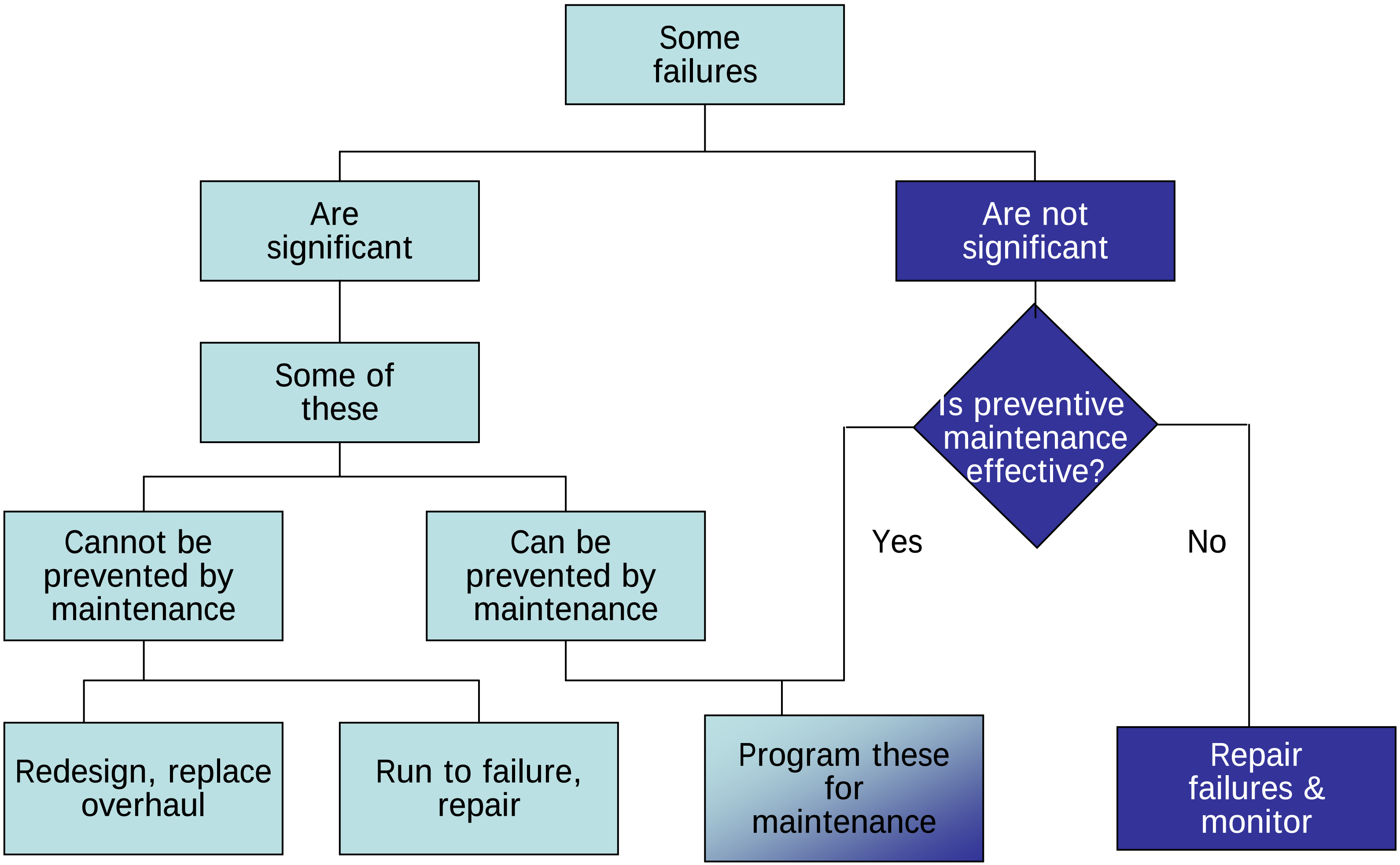
"Cause of Failure" Analysis
"Failure Mode" Analysis,
Condition-based Monitoring,
Predictive Maintenance &
"Reliability Centered Maintenance"

Management Engineering Environment GHD Clients People Performance

Our Investment "Toolkit"

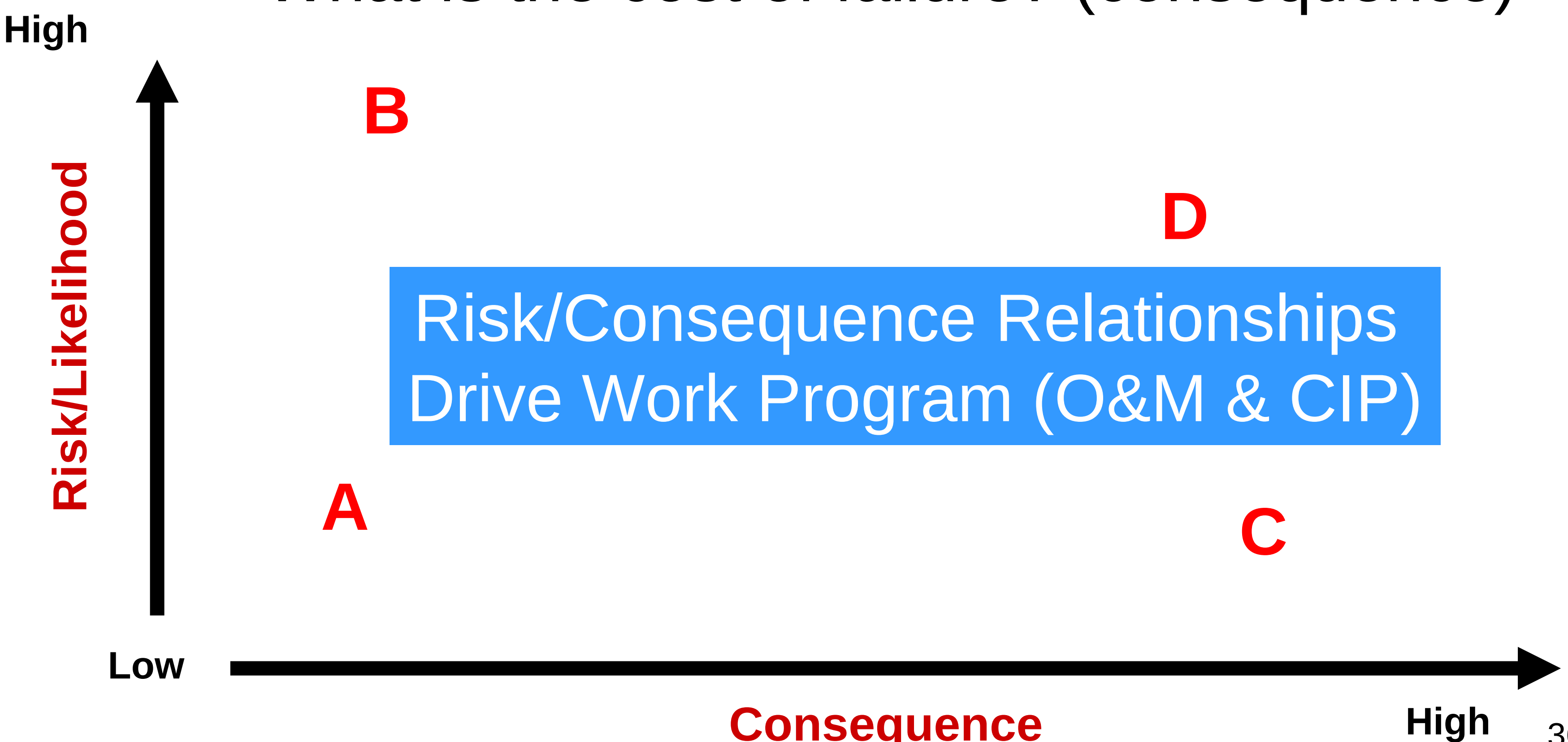
- Maintenance
- Renewal:
  - Major Repair –repair beyond normal periodic maintenance, relatively minor in nature, anticipated in the long-term operation of the asset; no enhancement of capabilities; typically funded by operating budget
  - Refurbish/Rehabilitation– replacement of a component part or parts or equivalent intervention sufficient to return the asset to level of performance above minimum acceptable level; may include minor enhancement of capabilities; typically funded out of capital budgets
  - Replace
    - Without enhancement – substitution of an entire asset with a new or equivalent asset without enhancement of capabilities
    - With enhancement - substitution of an entire asset with a new or equivalent asset with enhanced capabilities
- Augmentation

Failure-mode Based Management Logic

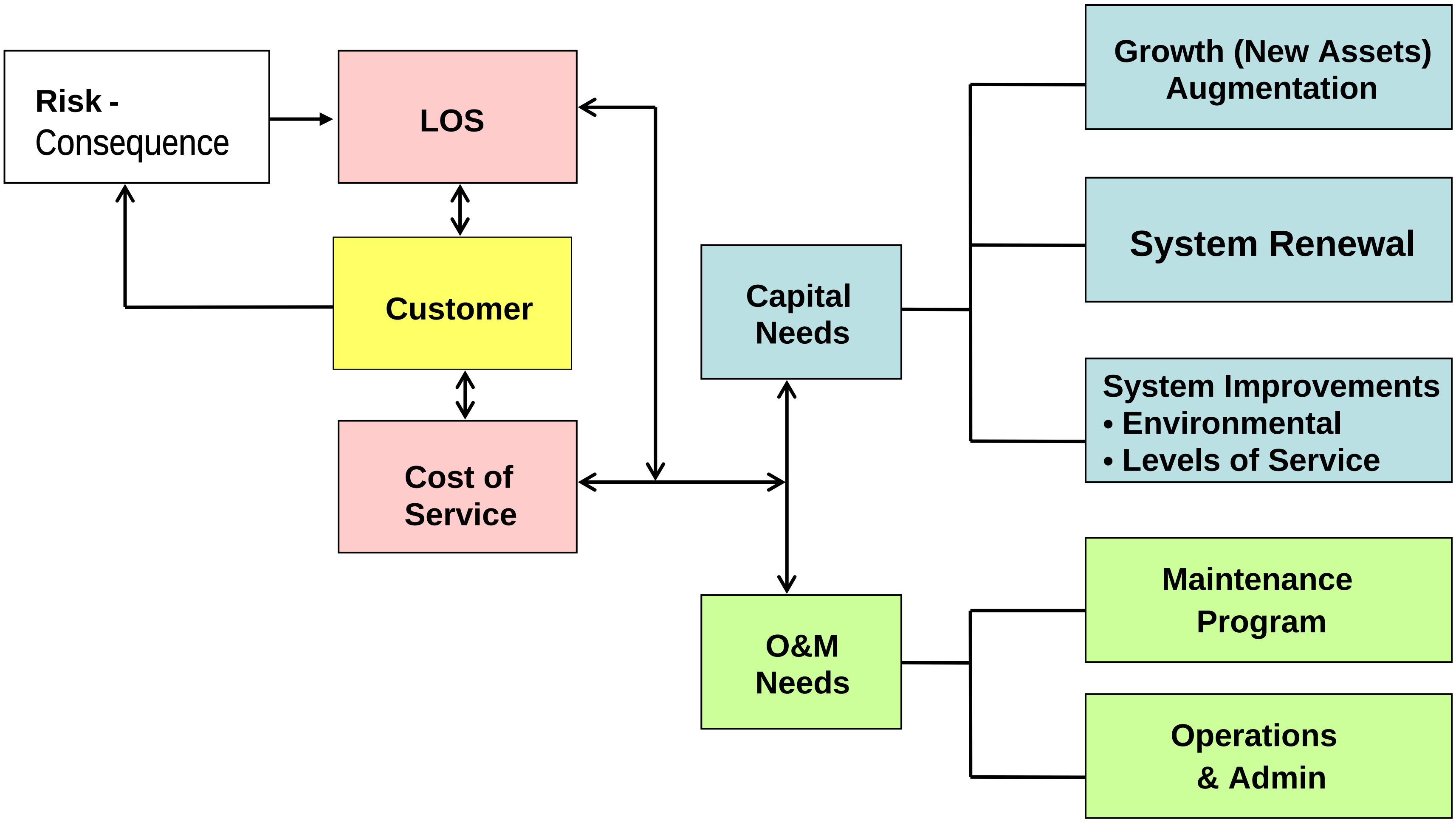


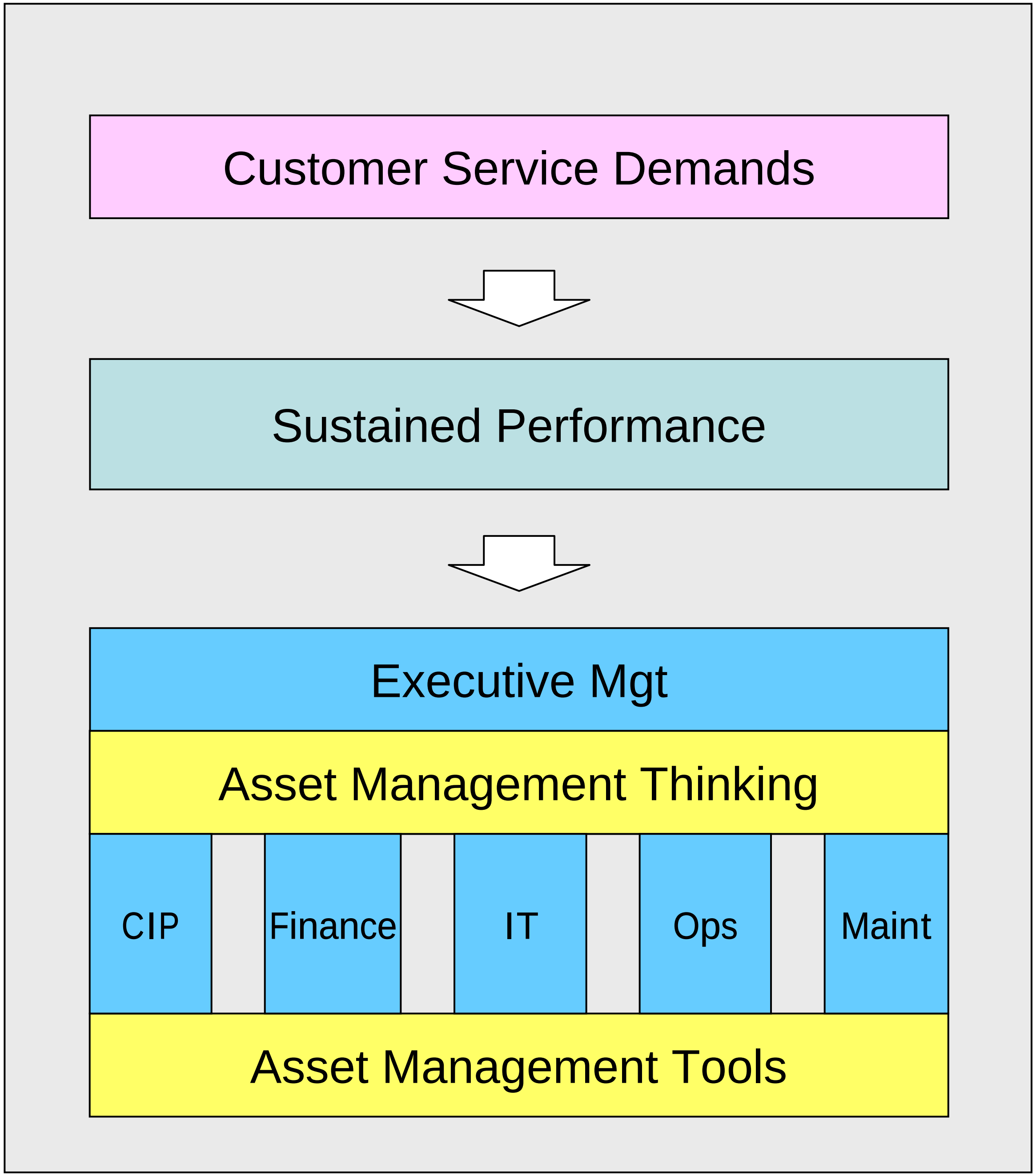
Determining "Significant" Failures: The Risk – Consequence Trade-off

- What is the likelihood of failure ? (risk)
- What is the cost of failure? (consequence)



The Big Picture





AM Oriented Structure

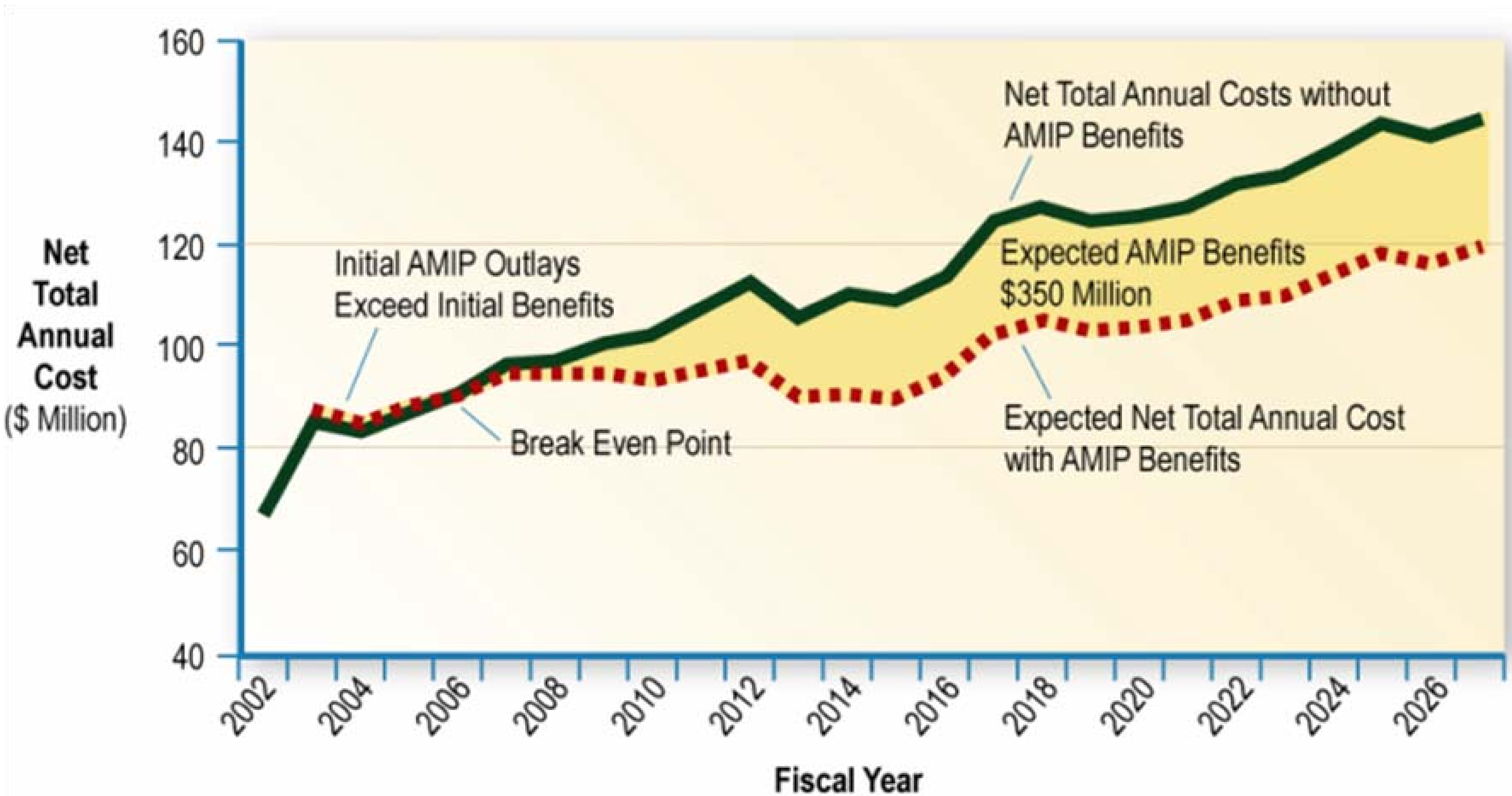
Better Decisions Produce Real "Savings"

Assessment of Australia's advanced asset management practices suggests:

20% to 30% Future Life Cycle Cost "Savings" for US Water/Wastewater Utilities

"Savings" = savings, cost avoidance, redirection of effort

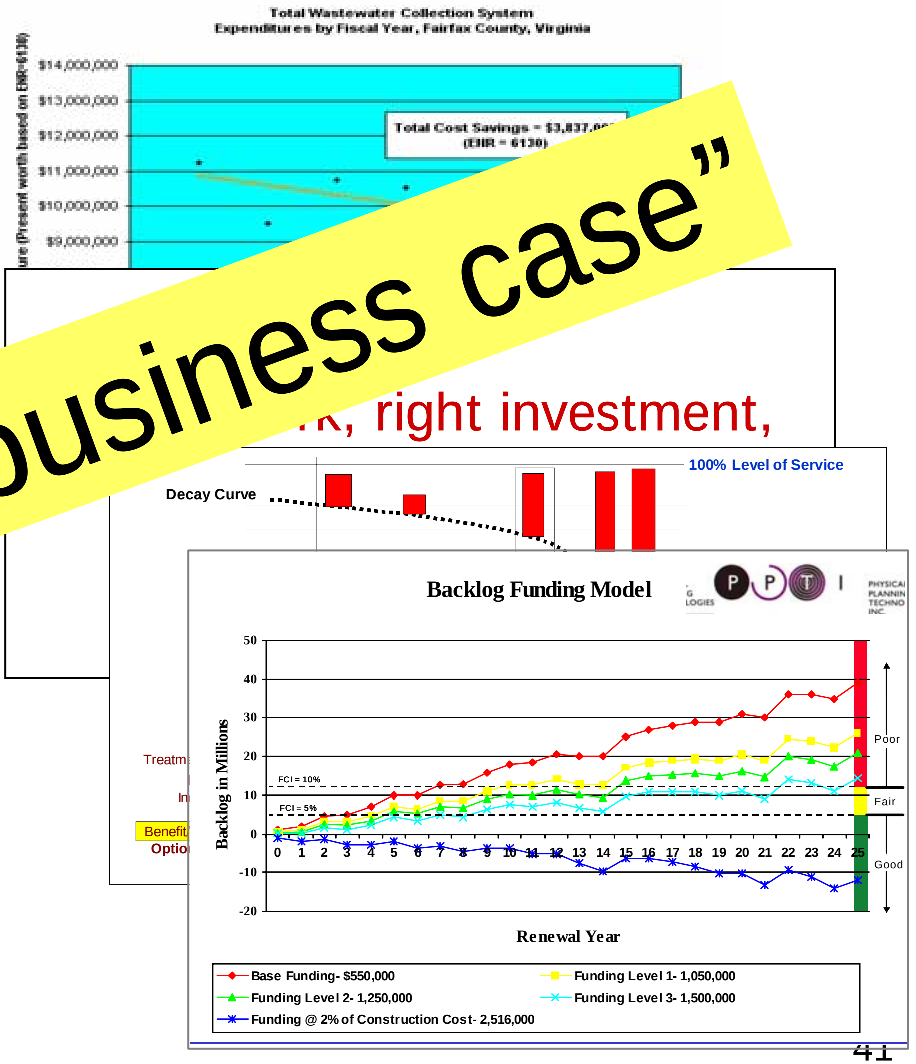
Making The AM Business Case



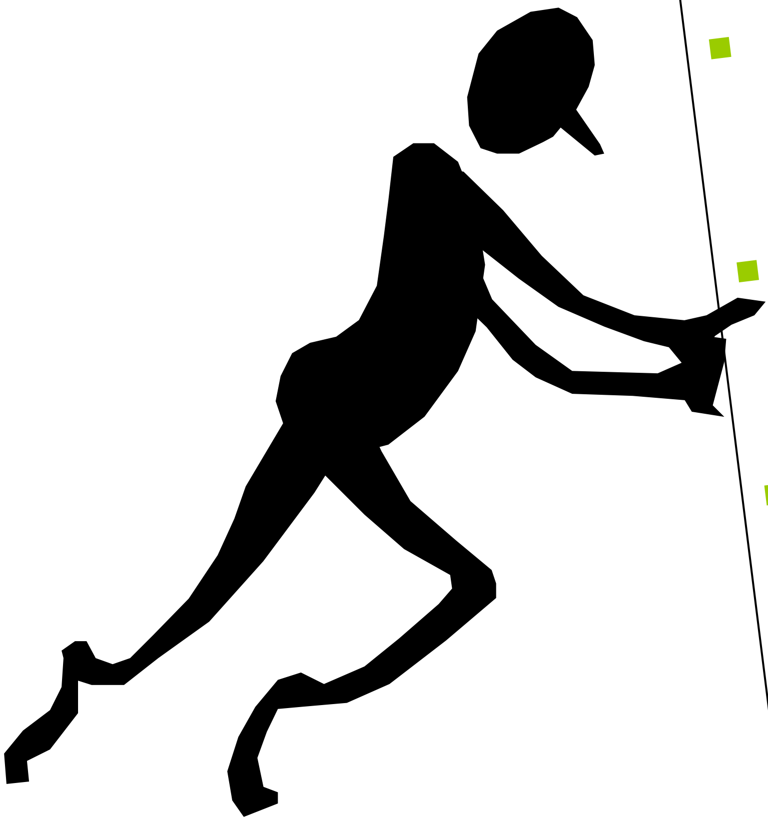
AM Payoffs

- Real reduced life cycle costs - better focused (redirected) resources
- Best "value per dollar spent"
- Cor ... in decision making

"Making a business case"



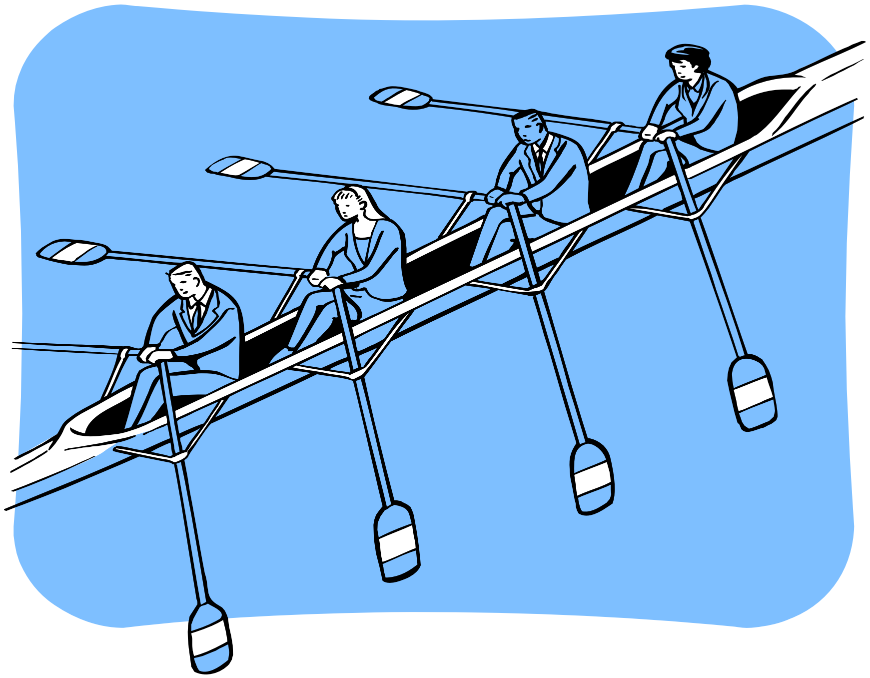
Realistic Expectations



- Will take several years of detailed, “nitty-gritty” work to fully deploy
- Will eventually require “buy-in”/commitment of the whole organization
- Requires “upfront” investment to get started, with “hidden” return for several years

“In short:
Asset Management Is A *Business Model*!”

- What we do
- Why we do it
- How we do it
- Where we invest
- What our costs are
- What our return is



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Storyline:

Microsoft Excel - EPA Seminar Master Sustainable Model .xls

Q17 f_x 5

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
7	Asset Hierarchy					Installed Date	Asset Class	Original Cost	Estimated Effective Life	Annual Dep	Accum Dep	Condition Rating	Residual Physical Life	% Asset Consumed (Physical)
8	Level 1	Level 2	Level 3	Level 4	Level 5	Year		$	Years	$	$	1 to 5		%
9	Name	Name	Name	Name	Name		Sheet B	Act or Est	Sheet B	Calculated	Calculated	Sheet A	Sheet B	Calculated
15			Pump Station											
16				Incoming Sewer										
17					Pipes	1963	3	$ 4,250	100	$ 43	$ 1,700	4	40	60%
18					Manhole	1963	3	$ 1,360	100	$ 14	$ 544	3	60	40%
19					Influent Gate Valve	1963	5	$ 442	30	$ 15	$ 589	5	6	80%
20				Incoming Power										
21					Pole & Transformer	1950	7	$ 2,550	30	$ 85	$ 4,505	1	30	0%
22					Connection	1963	7	$ 340	30	$ 11	$ 453	1	30	0%
23				Control system										
24					Incoming Telephone	1963	8	$ 85	25	$ 3	$ 136	4	10	60%
25					PLC	1983	8	$ 8,600	25	$ 344	$ 6,880	4	10	60%
26					Manual controls	1963	8	$ 170	25	$ 7	$ 272	3	15	40%
27					Connections	1963	8	$ 425	25	$ 17	$ 680	3	15	40%
28				Land & Improvemnts.										
29					Land	1950	10	$ 630	300	$ 2	$ 111	1		100%
30					Access Road	1963	1	$ 12,500	75	$ 167	$ 6,667	5	15	80%
31					Landscaping	1963	1	$ 1,275	75	$ 17	$ 680	4	30	60%
32					Security fence	1963	1	$ 425	75	$ 6	$ 227	4	30	60%
33				Sub Structure										
34					Cassion Outer	1963	1	$ 30,600	75	$ 408	$ 16,320	3	45	40%
35					Upper Floor	1963	1	$ 4,250	75	$ 57	$ 2,267	4	30	60%
36					Dry well	1963	1	$ 6,800	75	$ 91	$ 3,627	3	45	40%
37					Landings and Stairs	1963	9	$ 4,250	30	$ 142	$ 5,667	5	6	80%
38					Wet Well	1963	1	$ 5,100	75	$ 68	$ 2,720	3	45	40%
39					Shaped floor	1963	1	$ 850	75	$ 11	$ 453	4	30	60%
40					Sump pump	1963	1	$ 595	75	$ 8	$ 317	5	15	80%
41				Pumps										
42					Drive shafts	1963	4	$ 4,250	40	$ 106	$ 4,250	3	24	40%
43					Pumps	1963	4	$ 5,100	40	$ 128	$ 5,100	4	16	60%
44					Motors	1963	6	$ 4,250	35	$ 121	$ 4,857	4	14	60%
45				Electrics										
46					Meters & Fuses	1963	7	$ 1,275	30	$ 43	$ 1,700	4	12	60%
47					Switchboard	1963	7	$ 5,780	30	$ 193	$ 7,707	4	12	60%
48					Pump Starters	1963	7	$ 680	30	$ 23	$ 907	5	6	80%
49					Emergency connect.	2004	7	$ 2,210	30	$ 74	-$ 74	0		100%
50					Alarms / General L& P.	1963	7	$ 595	30	$ 20	$ 793	4	12	60%
51				Force Main										

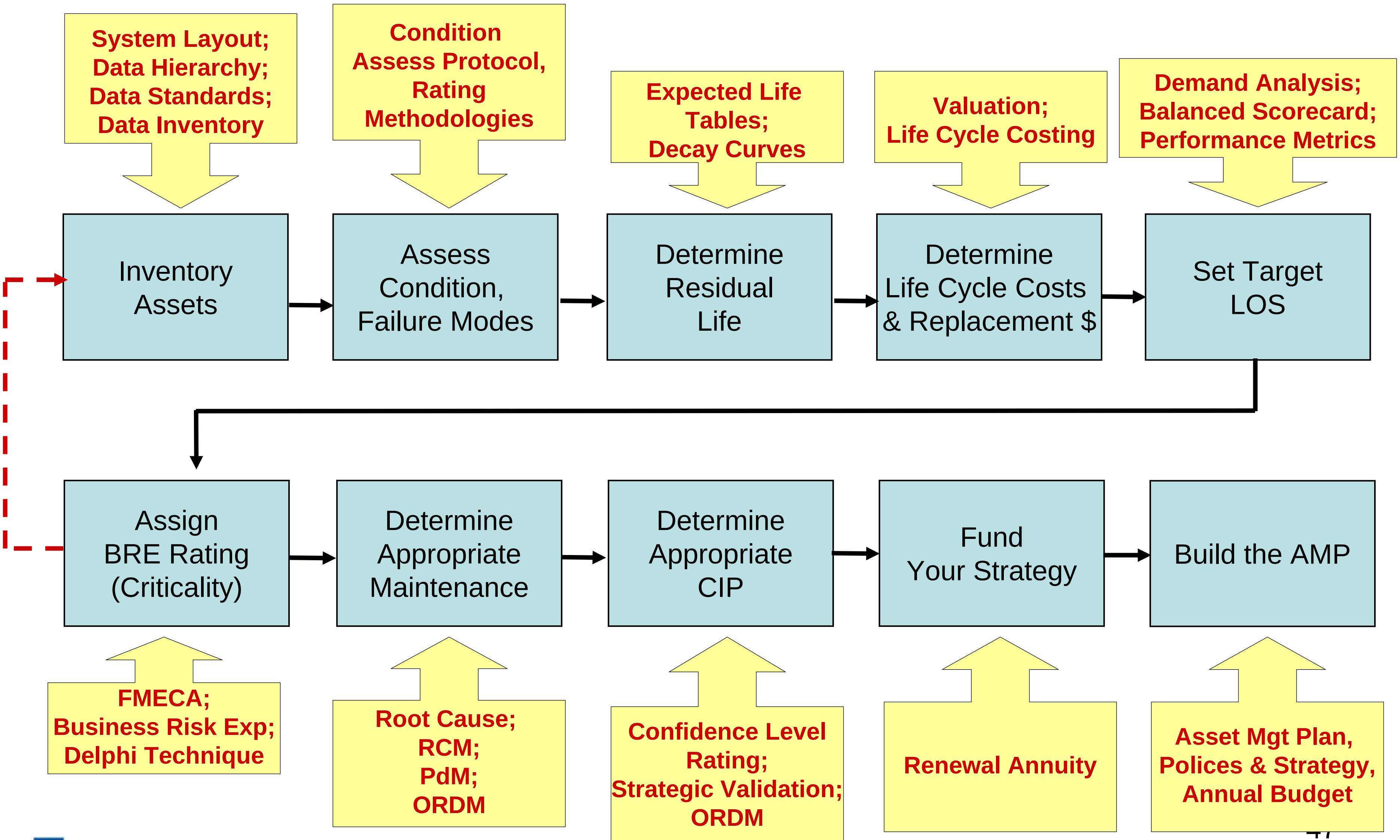
Answer Sheet / A - Condition / B - Residual Lives / C - Probabilty of Failure / D - Consequence of Failure

Ready NUM

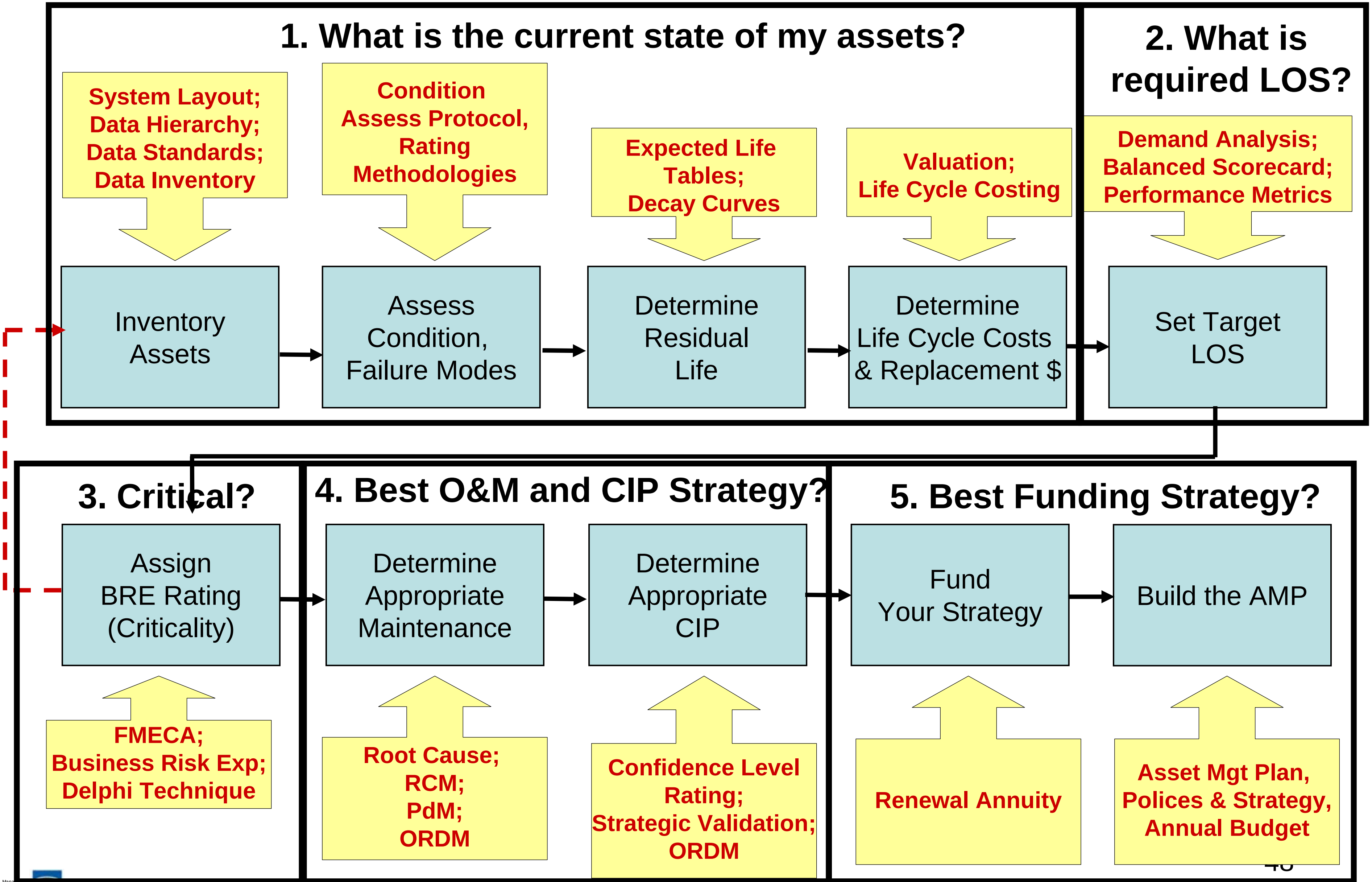
The Five Core AM Questions

Core Questions
1. What is the current state of my assets? • What do I own? • Where is it? • What condition is it in? • What is its remaining useful life? • What is its economic value?
2. What is my required sustained Level Of Service? • What is the demand for my services by my stakeholders? • What do regulators require? • What is my actual performance?
3. Given my system, which assets are critical to sustained performance? • How does it fail? How can it fail? • What is the likelihood of failure? • What does it cost to repair? • What are the consequences of failure?
4. What are my best "minimum life-cycle-cost" CIP and O&M strategies? • What alternative management options exist? • Which are most feasible for my organization?
5. Given the above, what is my best long-term funding strategy?

The 10-Step Asset Management Plan Process



Relating the “5 Core Questions” To The “10-Step AMP Process”



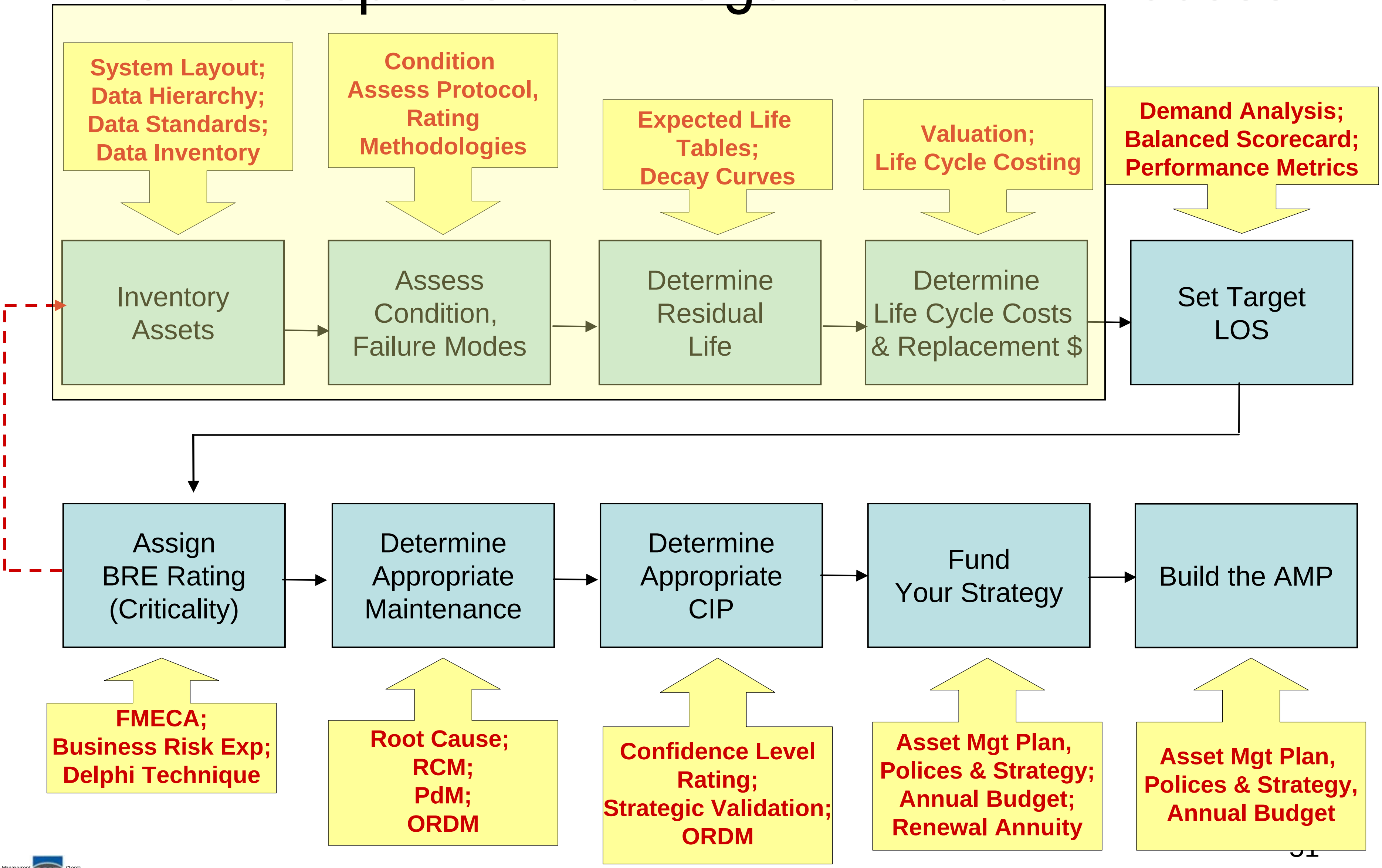
The Bear and the Butterfly

AGENDA

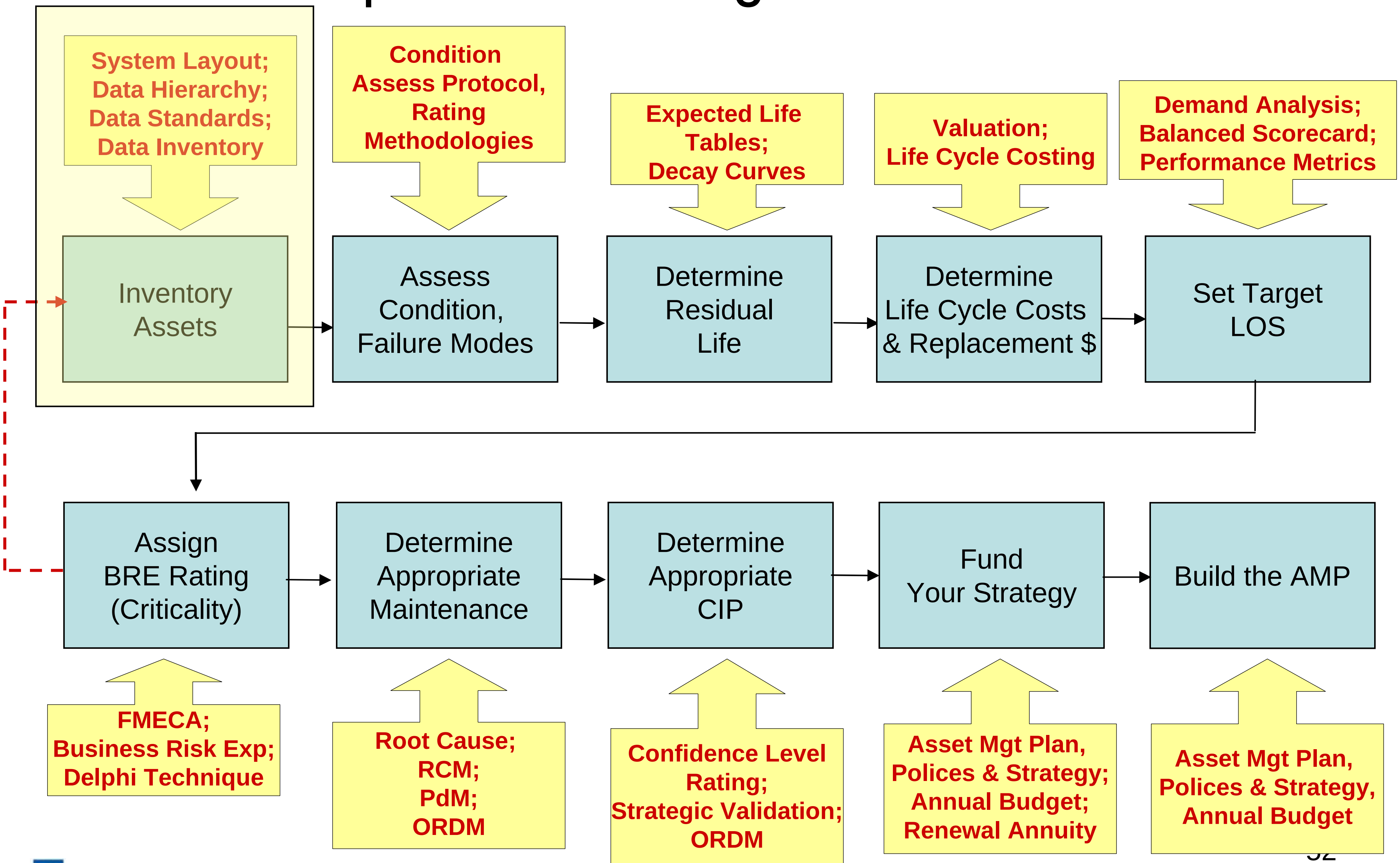
Day 1

- *Welcome, Introductions & Housekeeping Details*
- *“Storyline” Introduction, Background And Context*
- *Overview Of Fundamental Concepts & Core Practices*
- *The Storyline: Tom’s Really Bad Day*
- *Core Question 1: What Is The Current State Of My Assets?*
- *Core Question 2: What Is My Required “Sustainable” Level Of Service?*
- *Core Question 3: Which Assets Are Critical To Sustained Performance?*
- *Review of Key Slides; Discussion /Q & A*

The 10-Step Asset Management Plan Process



The 10-Step Asset Management Plan Process



Question 1: State?

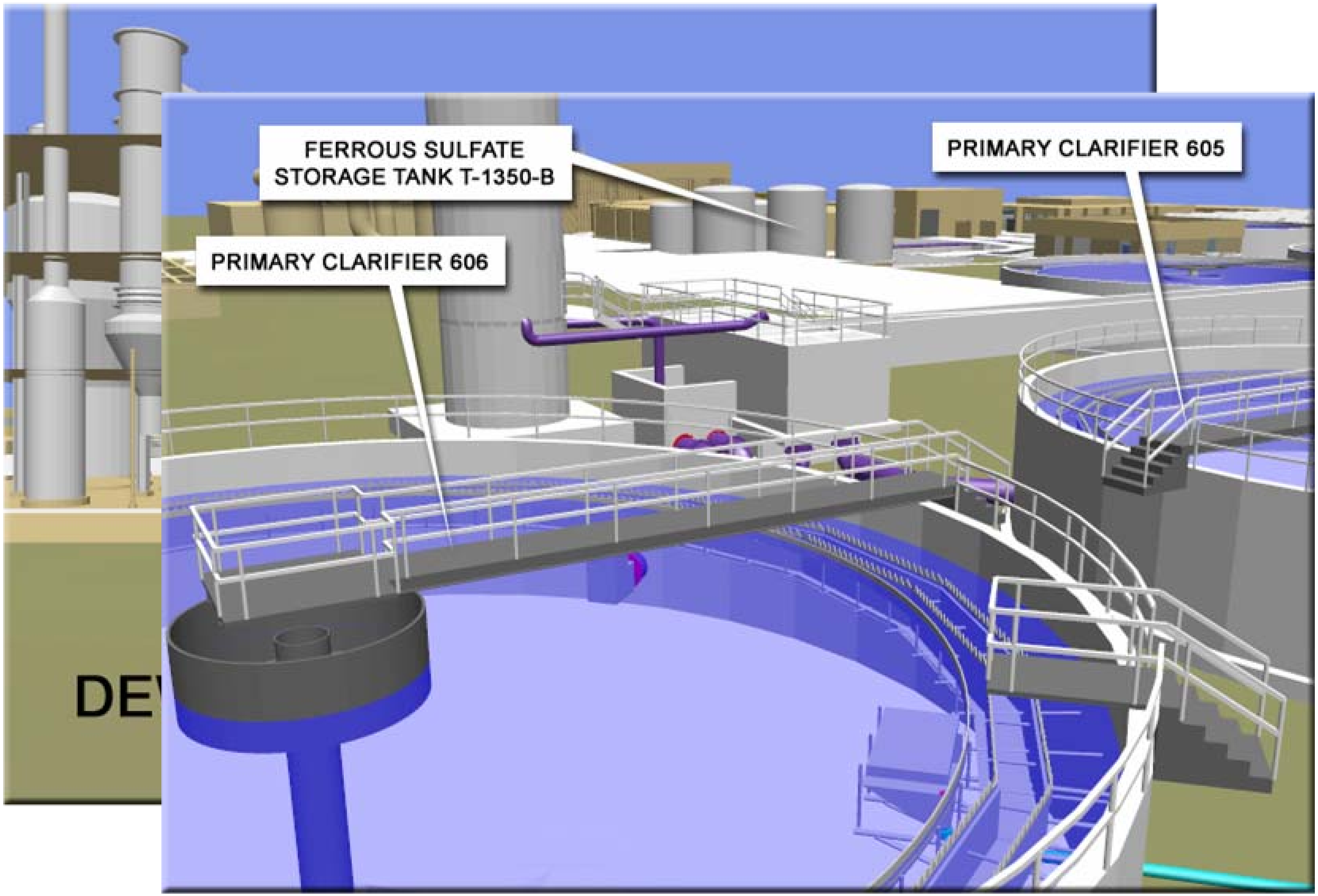
Core Questions
1. What is the current state of my assets?
• What do I own?
• Where is it?
• What condition is it in?
• What is its remaining useful life?
• What is its economic value?
2. What is my required sustained Level Of Service?
• What is the demand for my services by my stakeholders?
• What do regulators require?
• What is my actual performance?
3. Given my system, which assets are critical to sustained performance?
• How does it fail? How can it fail?
• What is the likelihood of failure?
• What does it cost to repair?
• What are the consequences of failure?
4. What are my best "minimum life-cycle-cost" CIP and O&M strategies?
• What alternative management options exist?
• Which are most feasible for my organization?
5. Given the above, what is my best long-term funding strategy?

Setting the Scene

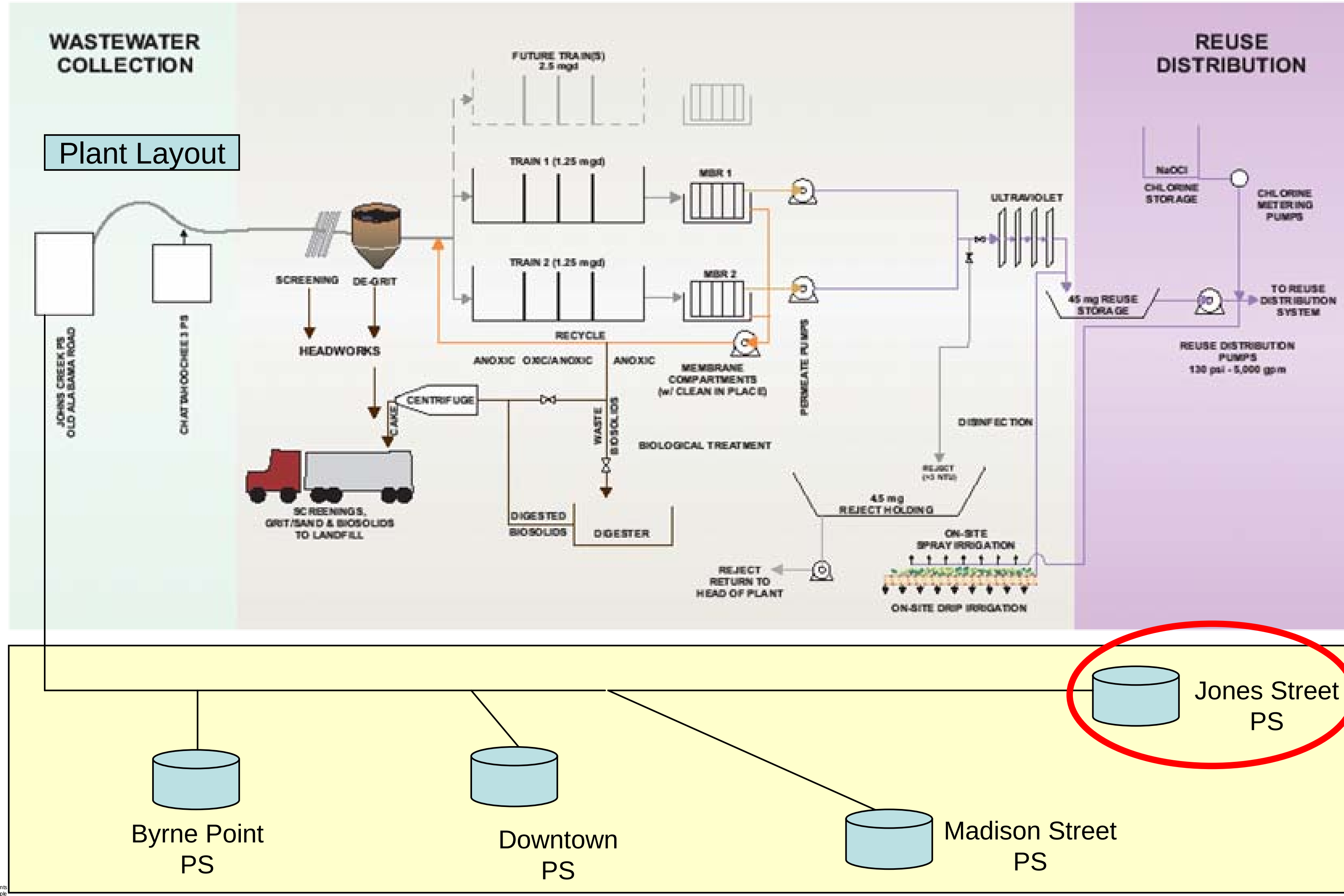
First some background ….

- *Four major failures over the last 18 months*
  - *Electrical switchboard & control panel*
  - *Pump Motor*
  - *Force main failure*
  - *Now the power pole …*
- *What does the station look like… ??*

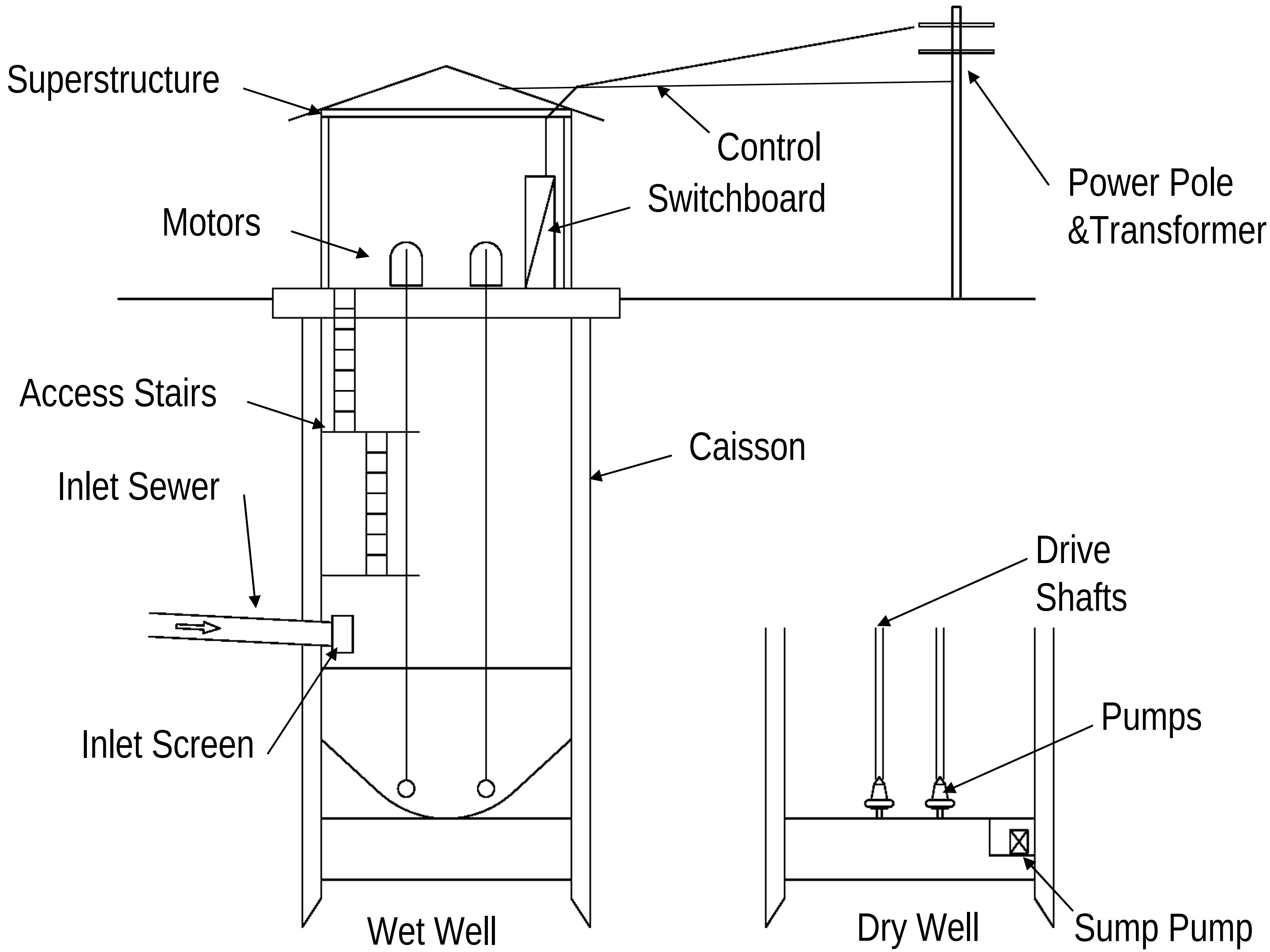
Sooo, Exactly What Is An “Asset”?



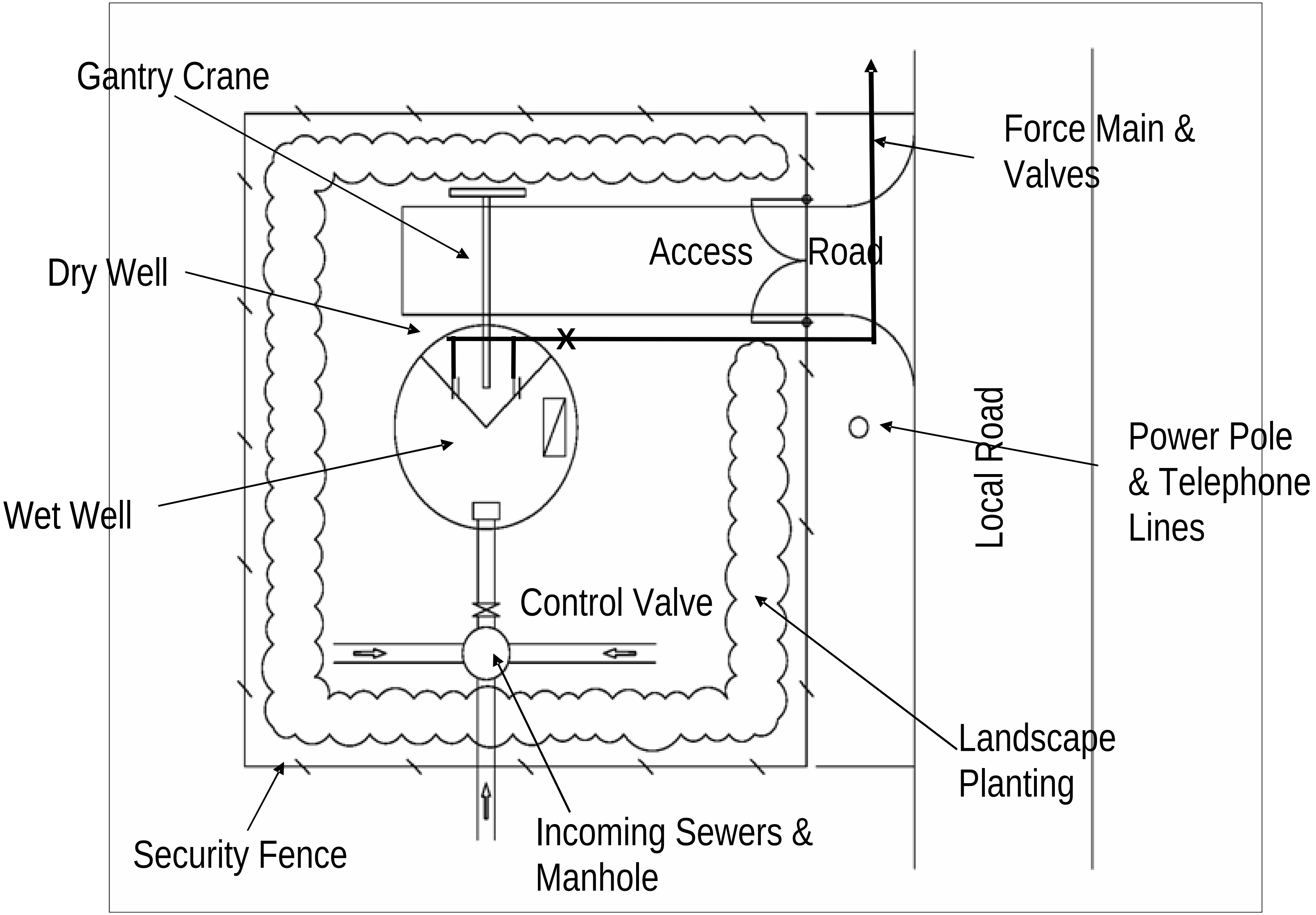
Tom’s “System Process Layout”



The Jones Street Pump Station



The Planimetric View



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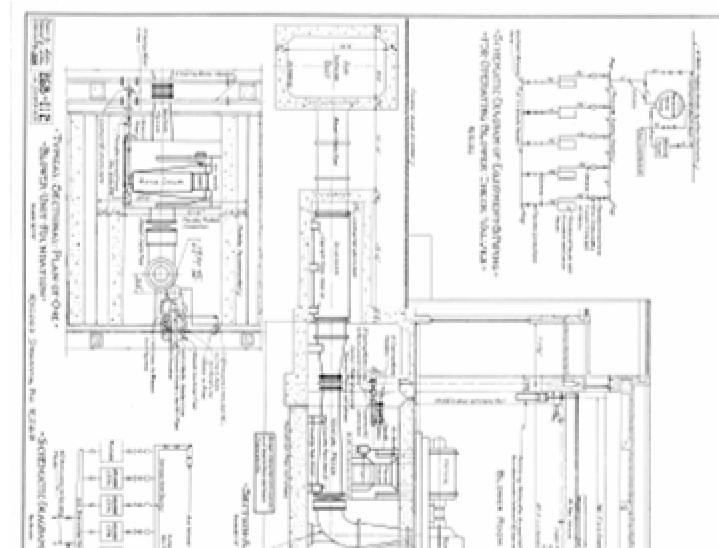
What is an “Asset Register”?

- A systematic recording of all assets that an organization owns or for which it has responsibility
- Built around an “asset identification number” to which attributes can be attached

Sources of Data

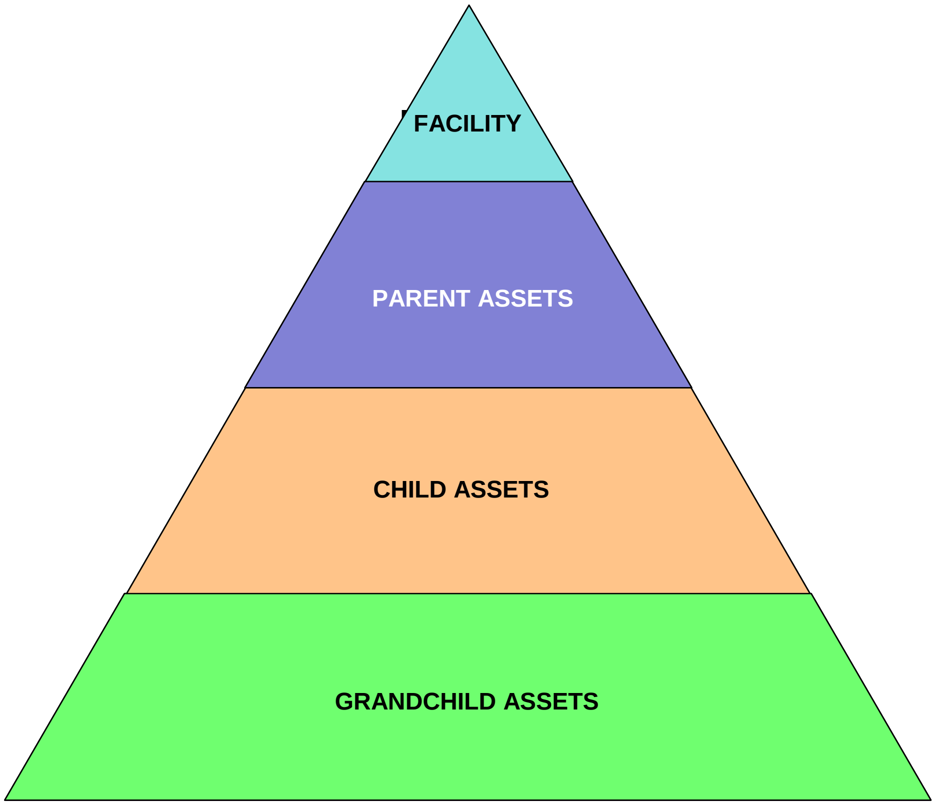
- ⇨ As-built drawings
- ⇨ Design drawings
- ⇨ Manufacturers Manuals
- ⇨ Bid documents
- ⇨ Schedules of quantities
- ⇨ Staff - current
  - previous
- ⇨ Photos and video!

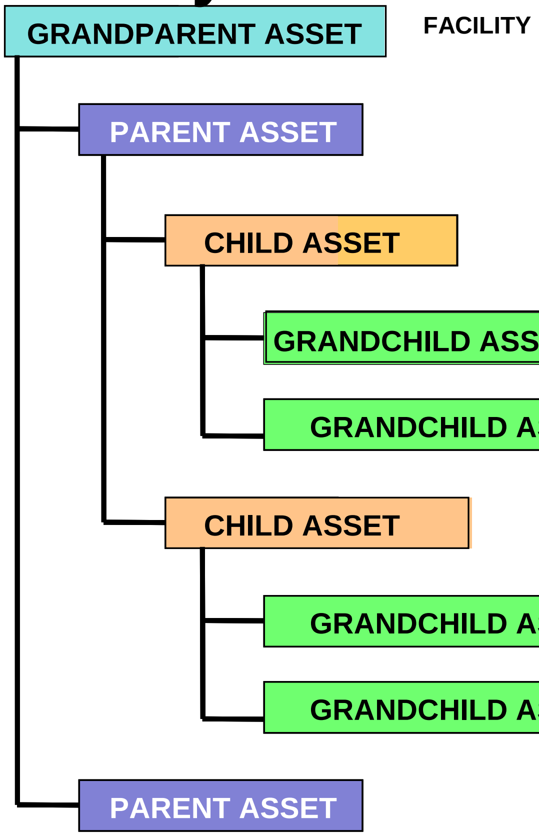


Types of Asset Registers

- ⇨ Hierarchical – Parent child
- ⇨ Category based
- ⇨ Process loops
- ⇨ Spatial Relationships – GPS generated
- ⇨ Business unit responsibilities
- ⇨ Service Provision

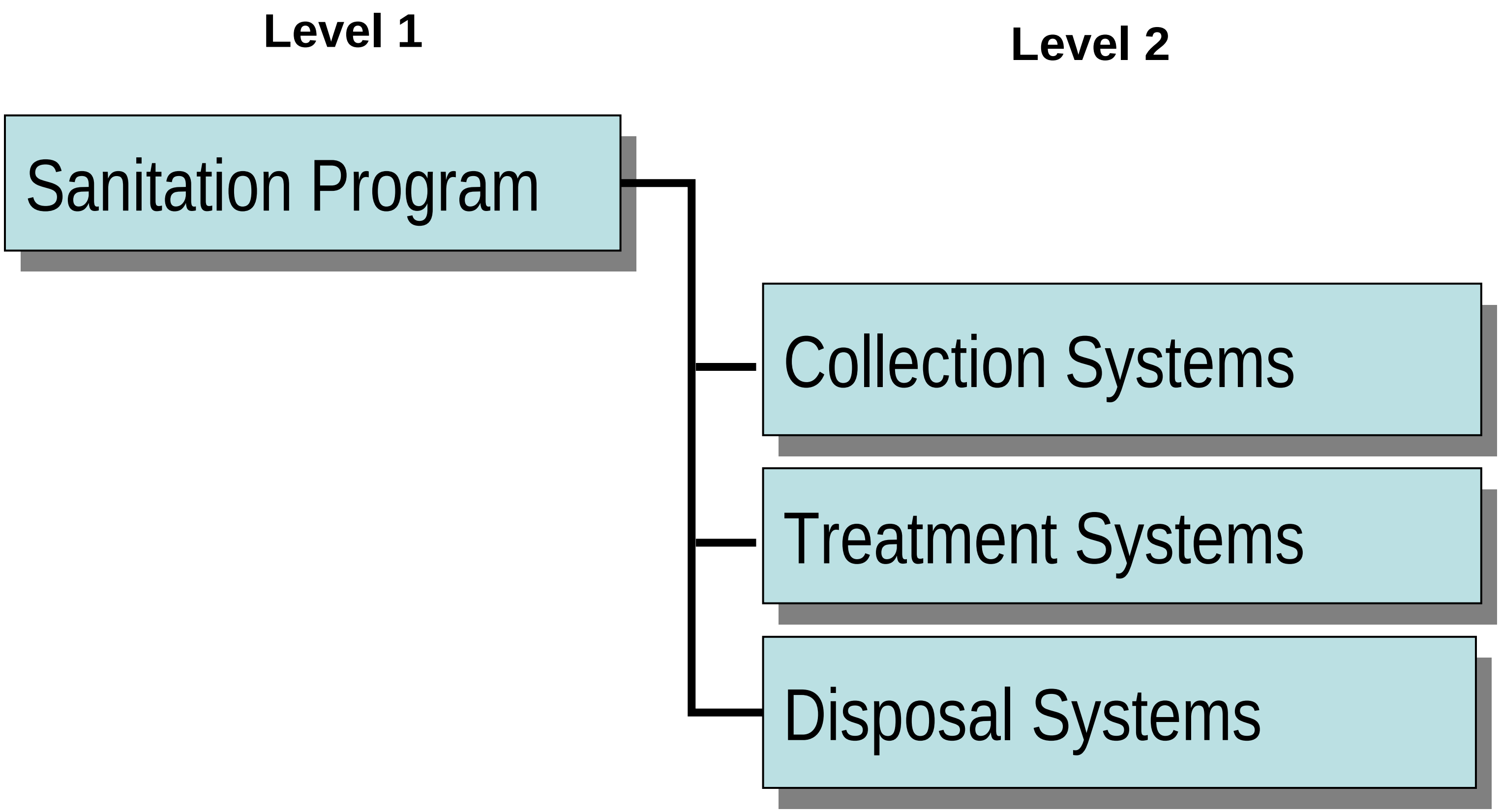
The Asset Hierarchy



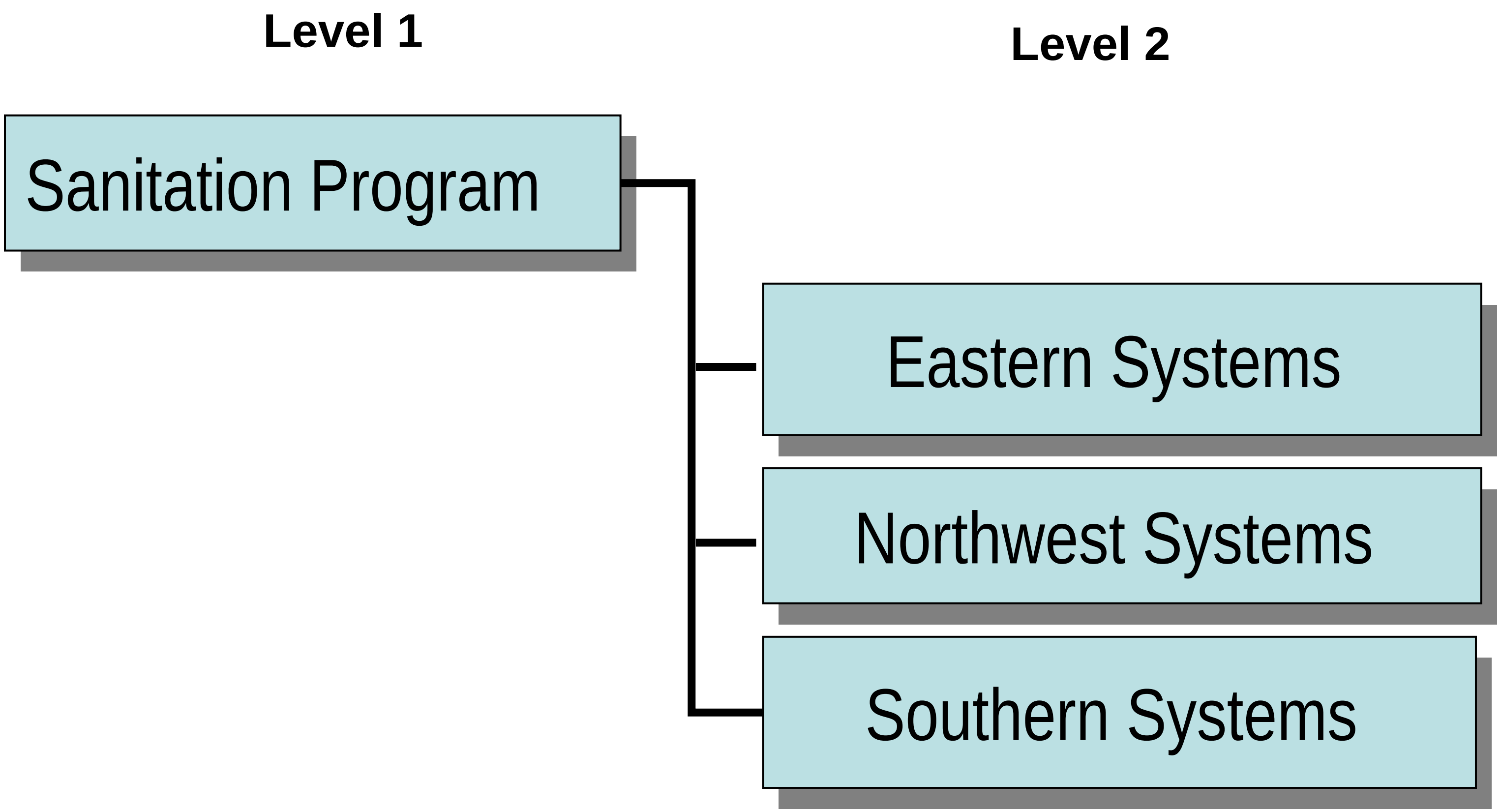


An agency's data standards are the backbone of its management capabilities

Hierarchical Structures



Hierarchical Structures



Hierarchical Structures

Level 2 | **Level 3**

- Collection System
  - Gravity Sewers
  - Siphon Structures
  - Pump Stations
  - Force Mains

Hierarchical Structures

Level 3

Level 4

- Gravity Sewers
  - Manholes
  - Pipelines
  - House Connections
  - Drop Structures
  - Sewer Ventilation

Hierarchical Structures

Level 3 | **Level 4**

- Pump Stations
  - Inlet Sewer & Screen
  - Wet Well / Dry Well
  - Superstructure
  - Pumps & Motors
  - Force Main
  - Electrics
  - Controls
  - Land & Surrounds

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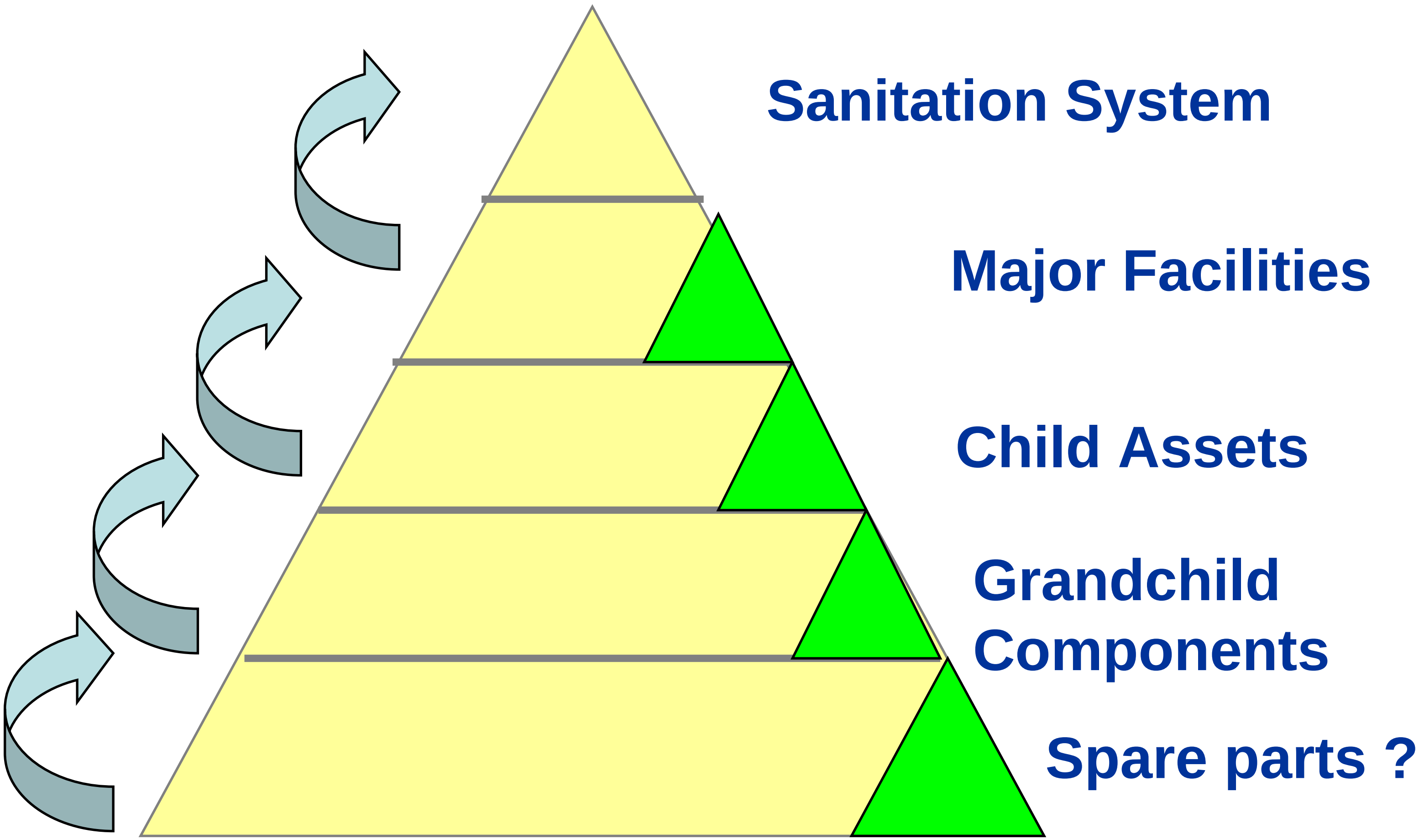
The “Roll-up” Concept



Confidence at the asset level is required to roll up Costs & Performance with confidence.

The “Maintenance Managed Item” (MMI)

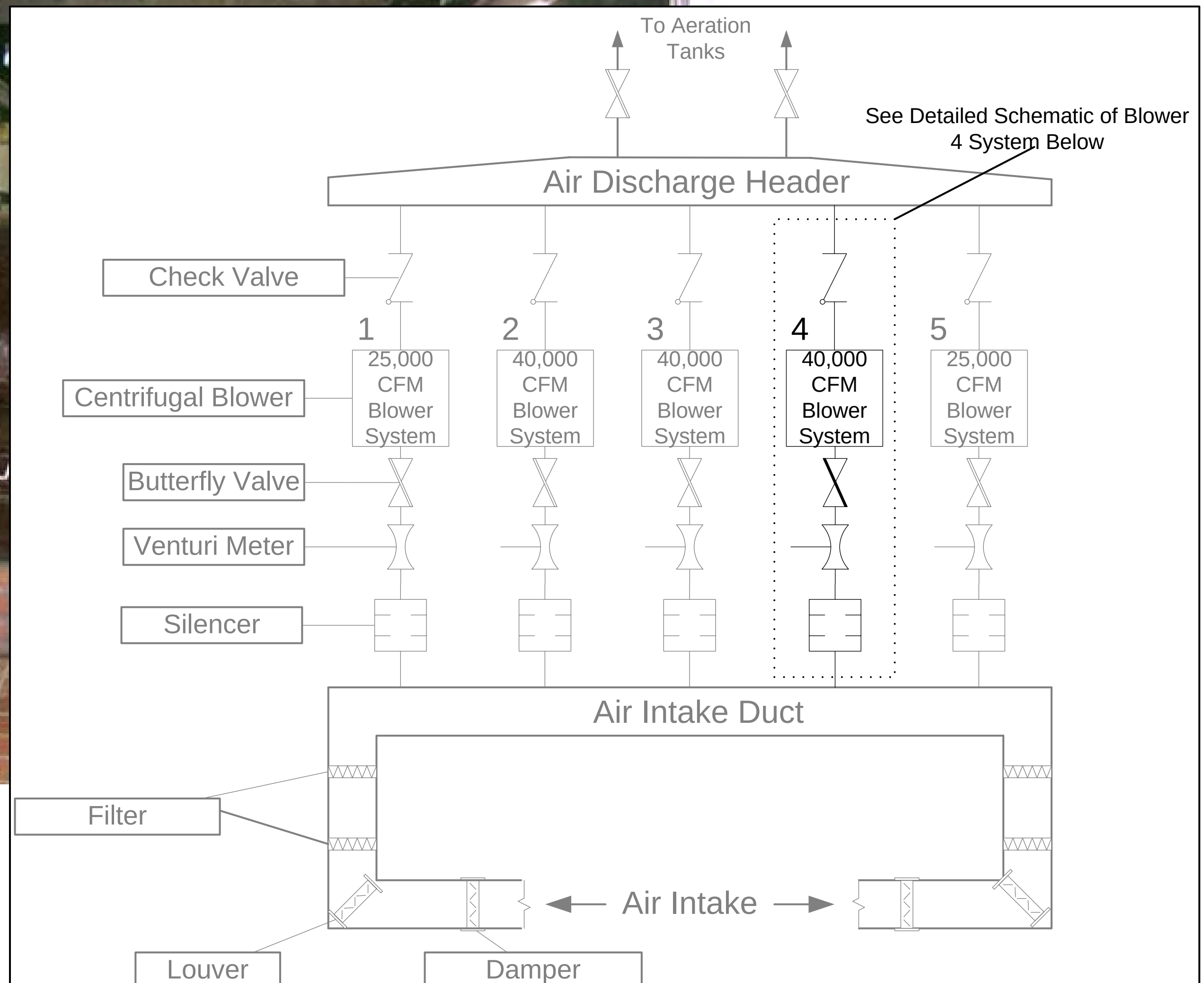
- "Maintenance Managed Item" or "MMI" refers to the lowest level of an asset's physical structure that is to be recognized within an asset register where the registry is structured as a nested hierarchy of physical assets.
- Typically, an MMI is set at that level of the hierarchy at which an asset is individually maintained or at which management decisions to repair, refurbish or replace are made.

Or?

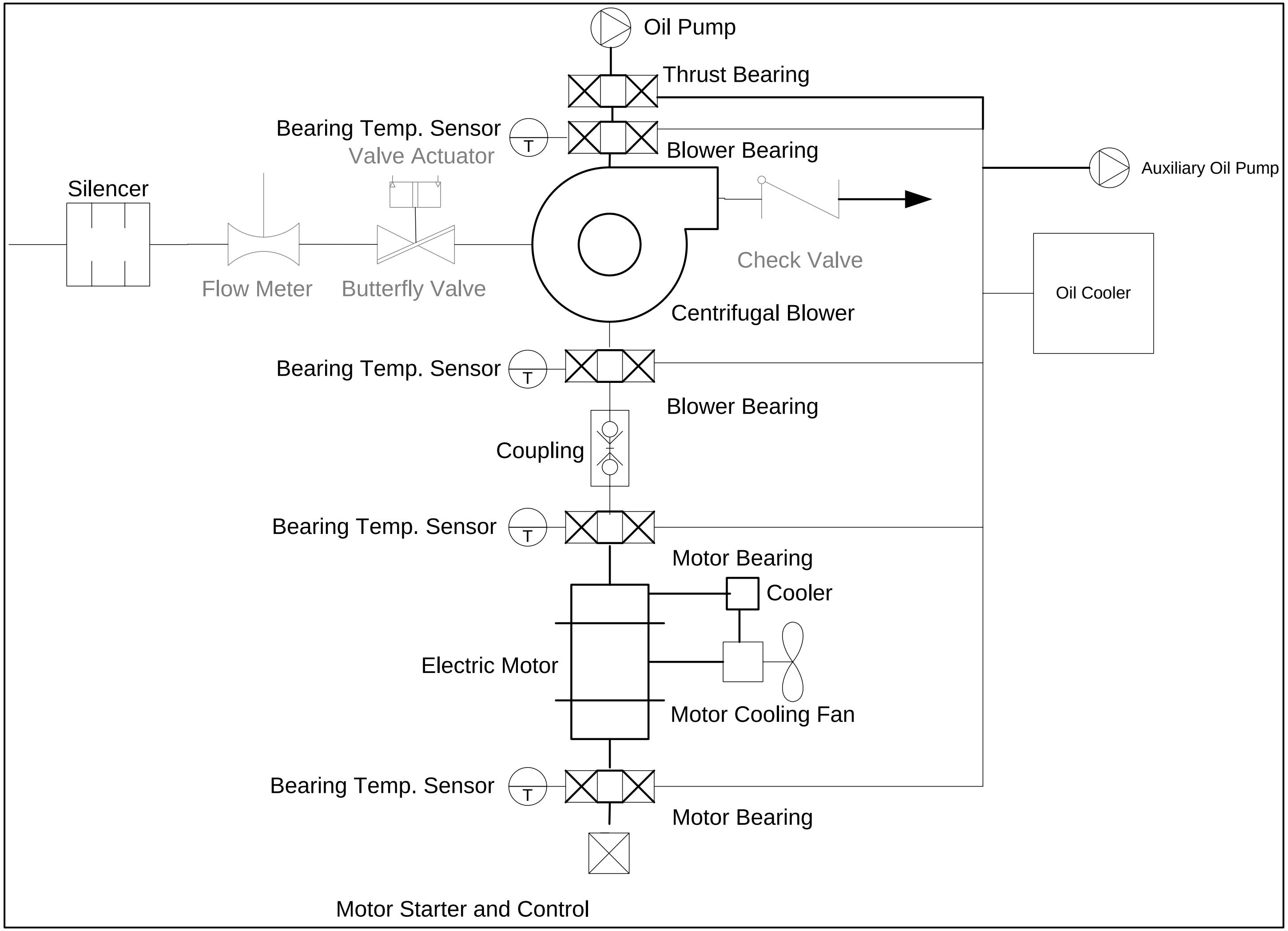
Maintenance Managed Items

ASSET TYPE	SUGGESTED REGISTER BREAK UP
PIPE ELEMENTS - Manholes - Pipelines - House Connections	 Individual manholes Pipelines between manholes House connections per pipeline
PUMP STATIONS	Split into pump well structure, inlet screens and valves, pumps, controls, electrics, rising main, valves, superstructure, ladders and landings
MAJOR FACILITIES	Split into individual assets Then split into individual components • Civil elements • Mechanical elements • Electrical elements • Other items

Using the Process Layout to Help Build the Register



Using the Process Layout to Help Build the Register



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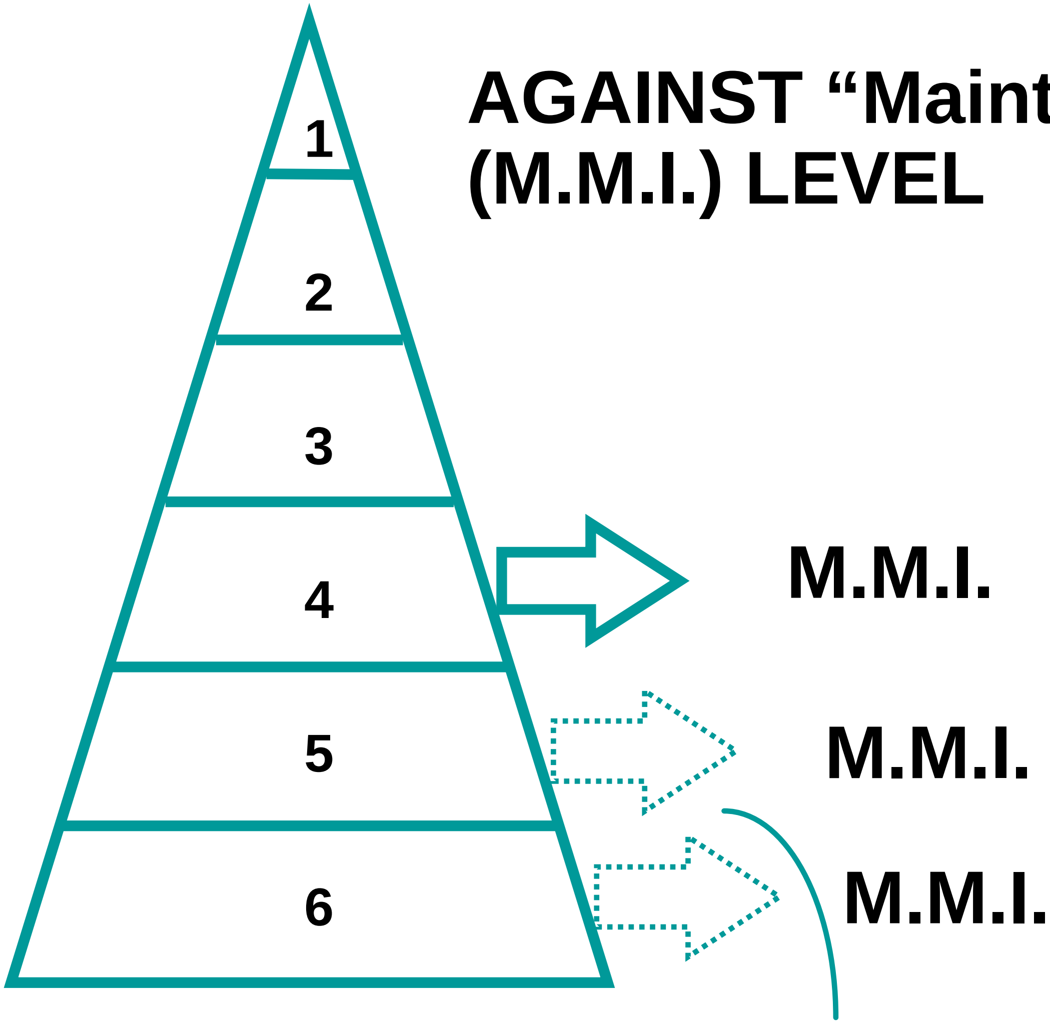
Tying Data to the Hierarchy

AGAINST "Maintenance Managed Item" (M.M.I.) LEVEL



HIERARCHY

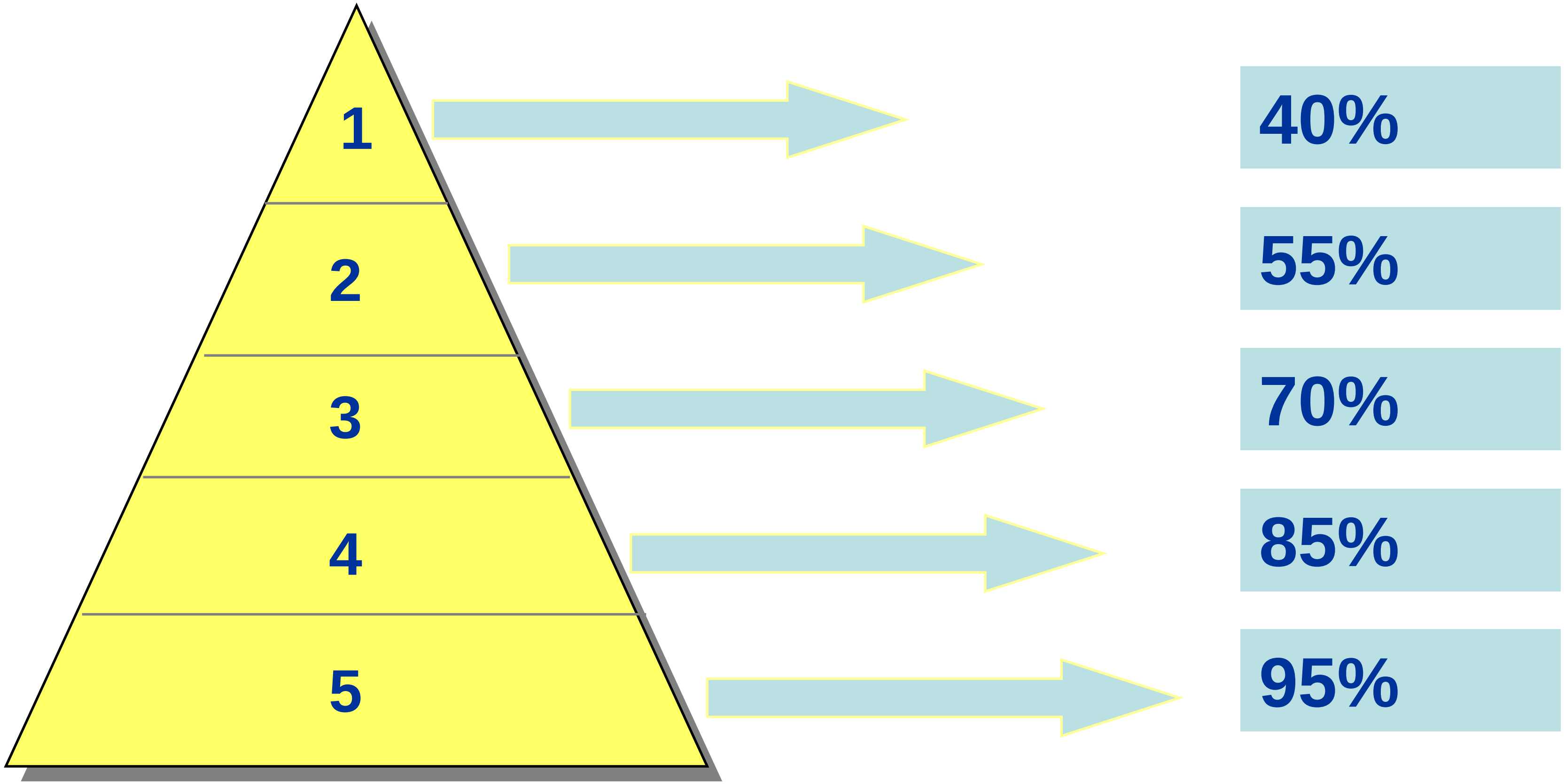
WHAT LEVEL IS WARRANTED?

MAINTENANCE DATA

- Planned or unplanned
  - + labor
  - + materials / spares
  - + plant
- Indirect impact on customers
- Failure codes
- Activity codes

Data – "Confidence Levels"

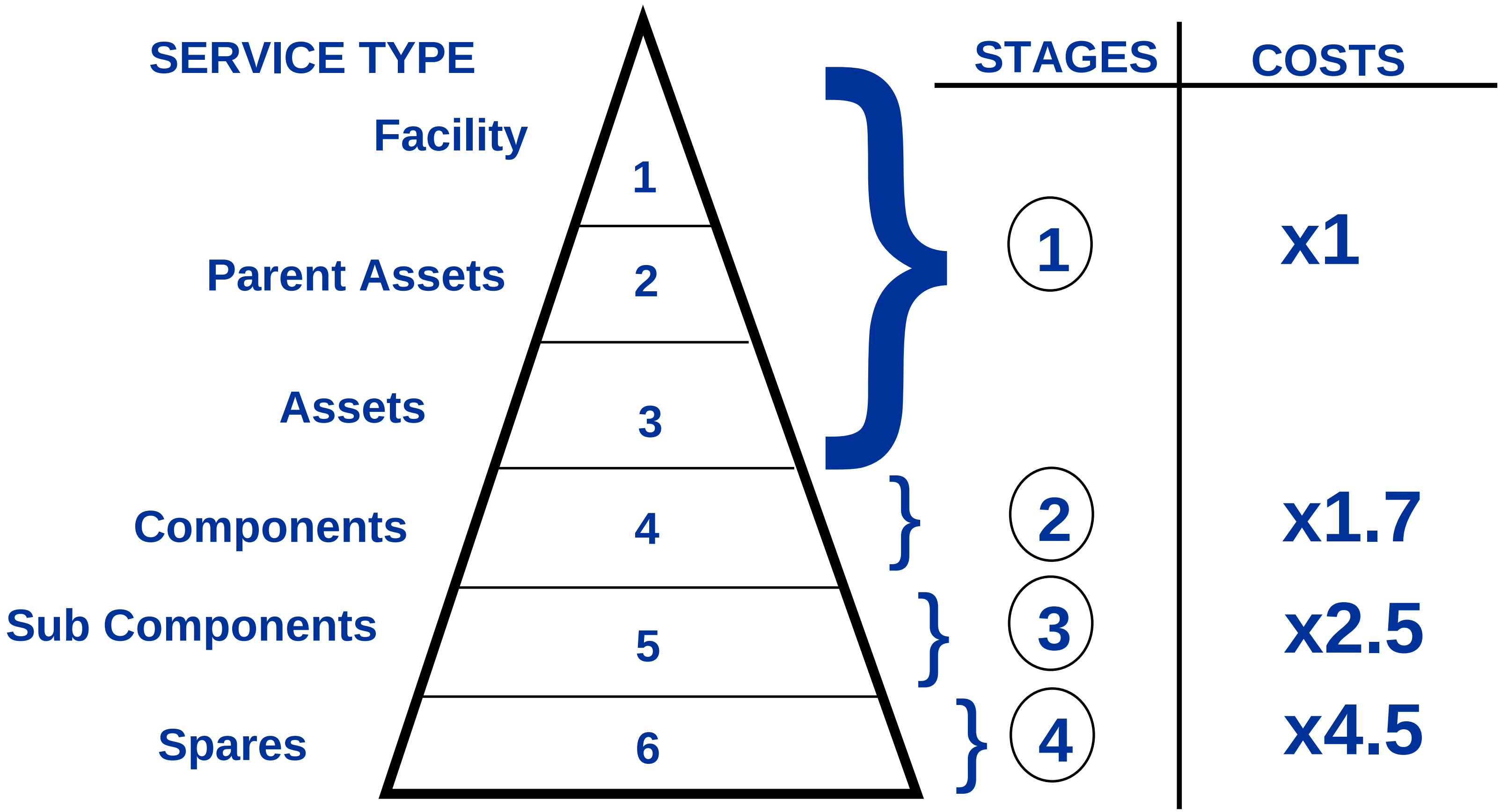
"Confidence Level" here means the confidence the decision-maker has that the decision rendered is the very best solution at the right time.



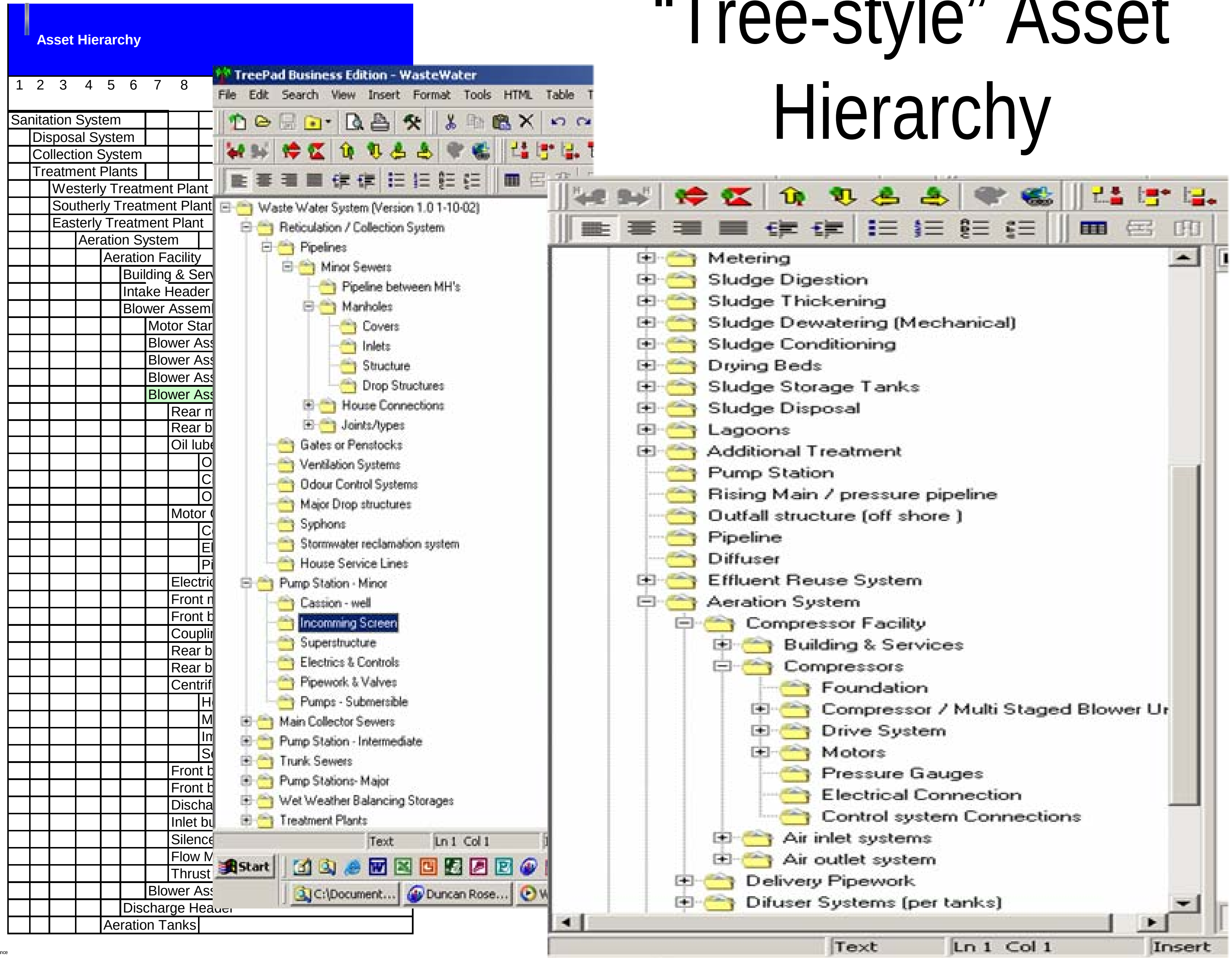
Data Hierarchy

AM Data levels – Costs .

Levels of Hierarchy - Staging

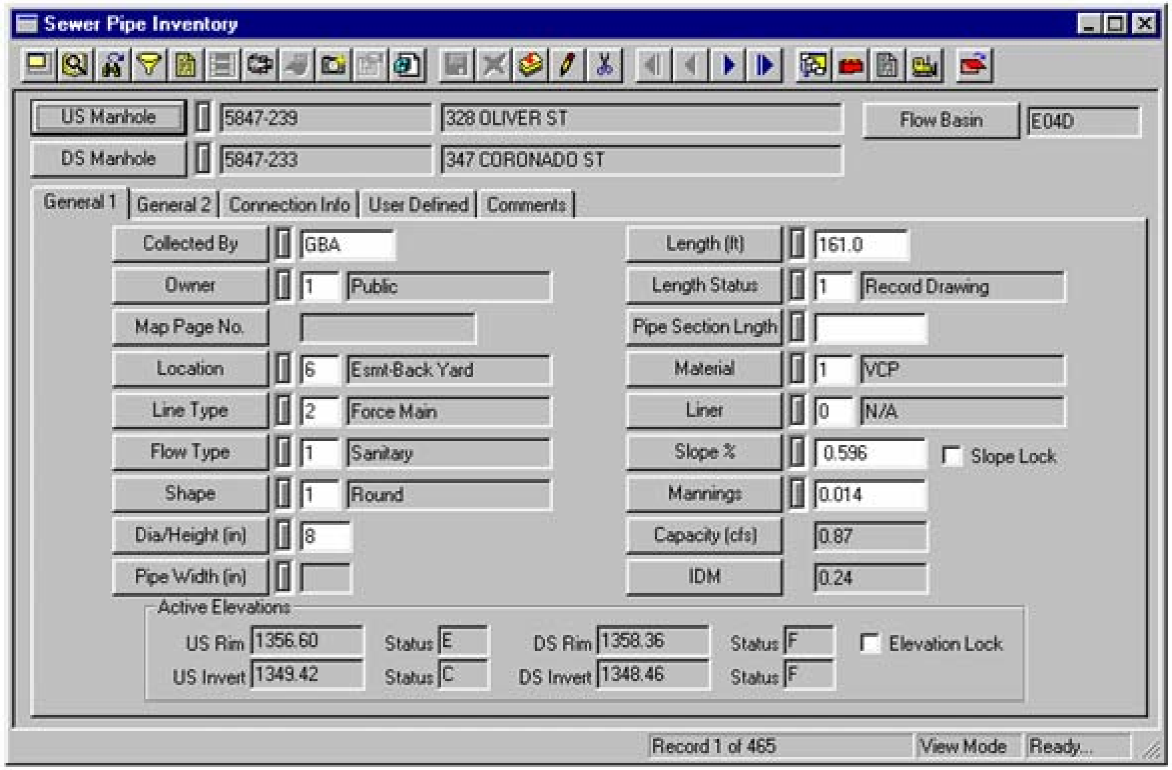


“Tree-style” Asset Hierarchy



The "Data Standard"

- Asset ID naming convention
- Attributes
- Record layout
- Database architecture & protocol
- Data collection protocols



Asset ID Naming Convention Issues

- What is "an asset" (what gets a unique ID?)
- "Linear" (pipe) versus "vertical" (plant) assets
  – Geo-reference
  – CAD versus GIS
- Active versus passive
  – Lock-out/tag-out
  – "Asset ID" versus "asset location" for mobile assets

"How Will I Use This Info" Drives Collection Strategy

DATA / ATTRIBUTE	SOURCE	LEVEL	USE
Asset Hierarchical Structure	Synergen/ Drawings	Asset	
Asset ID / Number	Synergen / Data Standard	Asset	
Asset Type	Synergen / Data Standard	Asset	
Installation / Replace Date	Drawings, 'Delphi'	Asset	Renewal Timing
Last Rehab Date	'Delphi'	Asset	Renewal Timing
Size / Capacity	Drawings / Field Inspection	Asset	CoF, Valuation
Size / Capacity Unit	Drawings / Field Inspection	Asset	CoF, Valuation
System Capacity	Drawings / Field Inspection	Asset	CoF
Length	Drawings / Field Inspection	Asset	Valuation
Length Unit	Drawings / Field Inspection	Asset	Valuation
Condition	Inspection, 'Delphi', Testing	Asset	Renew Timing, PoF
Reliability	'Delphi'	Asset	Renew Timing
Performance	'Delphi'	Asset	CIP Development
Effective Lives	Consultant	Type	Renew Timing
Unit Cost	Consultant	Asset / Type	Valuation
Replacement Cost	Consultant	Asset / Type	Valuation
Purpose	Drawings / Field Inspection	Type	CoF
Process	Drawings / Field Inspection	Asset	CoF
Redundancy	Drawings / Field Inspection	Asset	PoF
Potential for Injury	Drawings / Field Inspection	Type	CoF
Time to Rectify	Consultant	Type	CoF
Existing Planned CIP	Delphi'	Asset	Renewal Timing
Planned CIP year	Delphi'	Asset	Renewal Timing
Status	Field Inspection, 'Delphi'	Asset	

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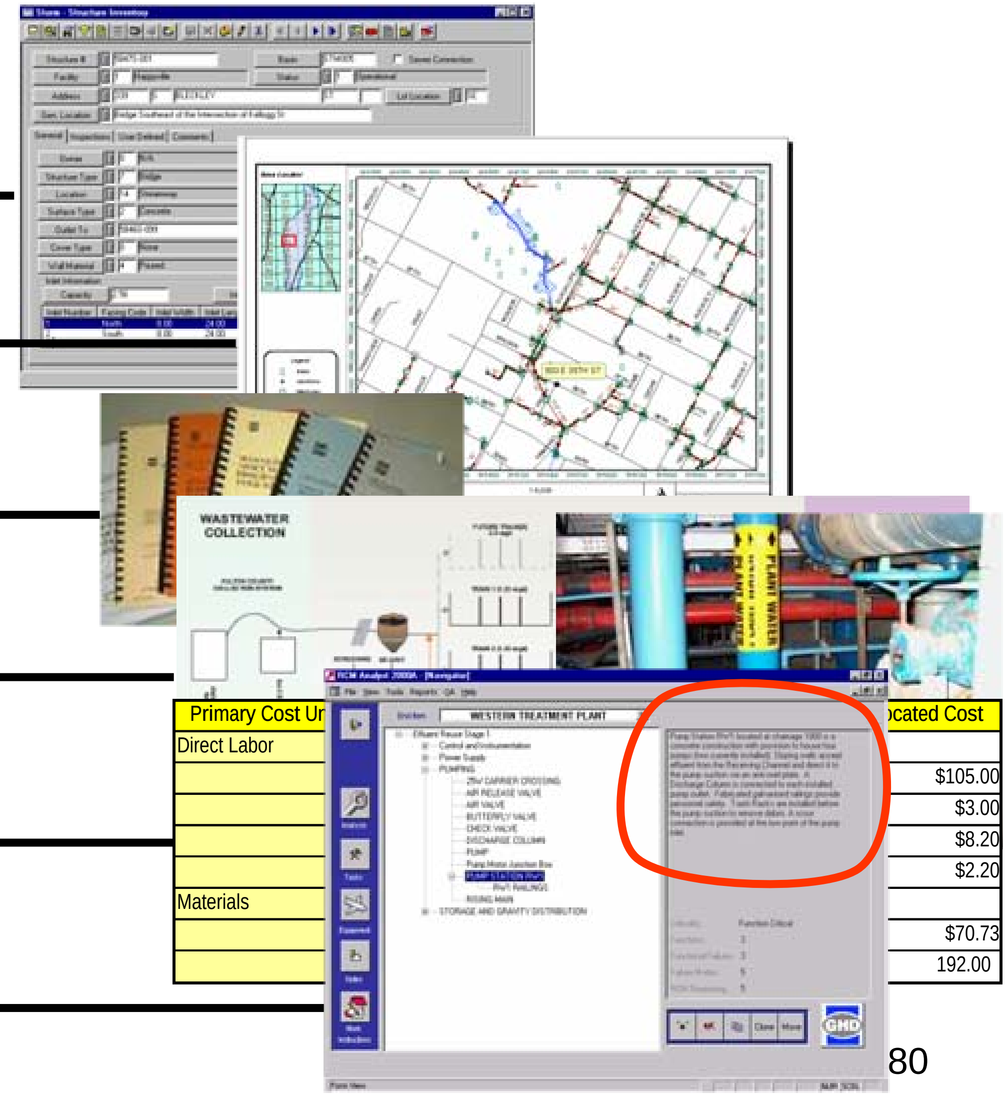
The Data Standard: The Major Components of Asset Data

Asset ID:

- Physical Attributes
- Geo-reference
- O&M Manuals
- Drawings/Photos
- Life Cycle Costs
- Knowledge & Strategy



Generating Registry Data – Two Different Tasks

- Retrospective (“What we already have”)
  - “Critical first”
  - Use existing crews as they respond to Work Orders
  - Engineering students

- Prospective (“What we are about to acquire”)
  - Tie to “commissioning/ handover” process
  - Use contract retainage to control

New Technology – Recording Data

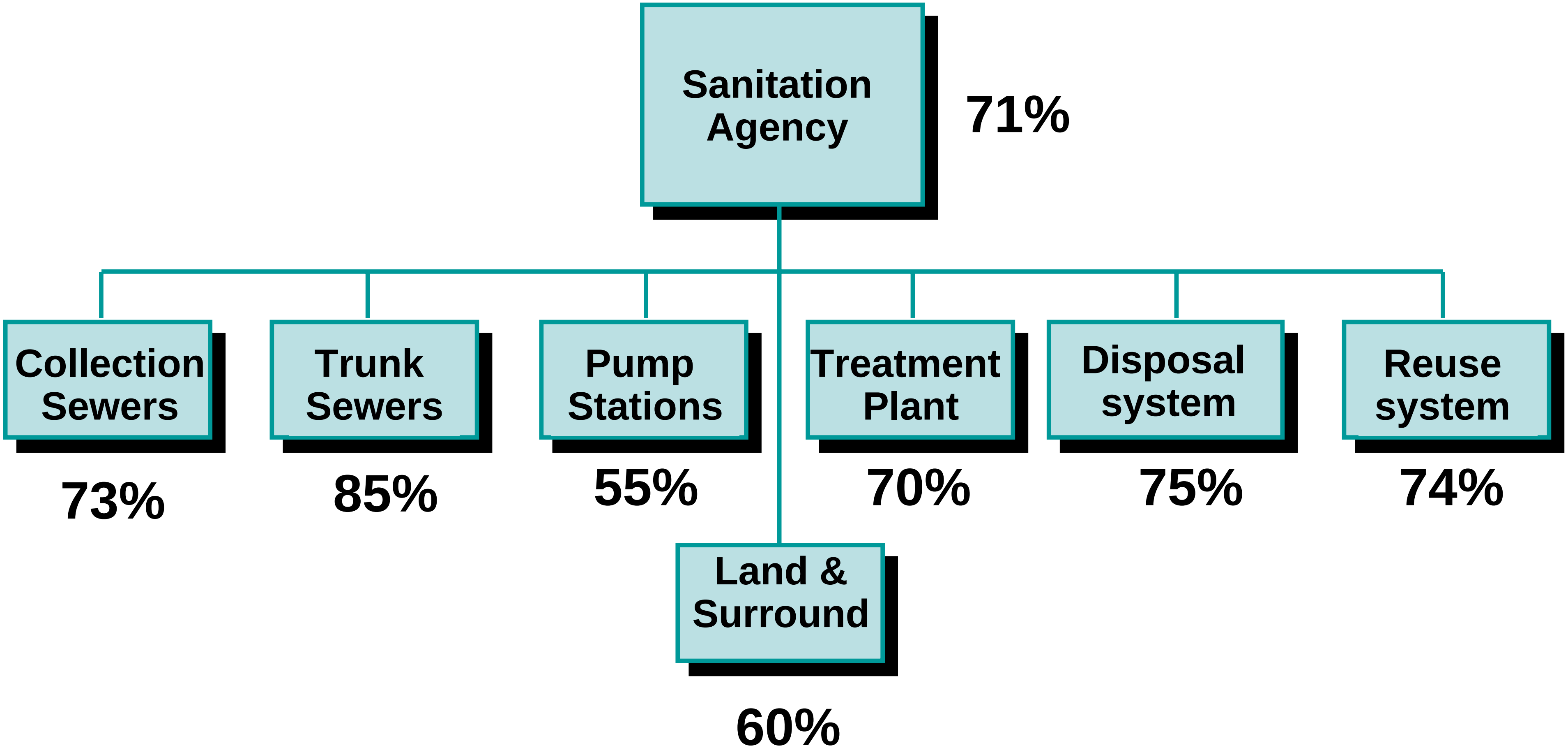
Ricoh Caplio 3

Data Responsibilities – Pump Station?

Who has responsibilities in your Agency?

⇨ Asset Details	Operations
⇨ Condition Assessment	Maintenance
⇨ Asset Values	Engineering
⇨ Residual Physical Lives	Engineering
⇨ Probability of Failure	Maintenance
⇨ Consequence of Failure	Engineering
⇨ Business Risk Exposure	Engineering
⇨ Optimal Renewal Strategy	Maint/Engineering

Ensuring Business Uniformity



RATING THE INDIVIDUAL DEMANDS FOR RESOURCES BY USING CONFIDENCE LEVEL SCORES

Management Engineering Environment GHD Clients People Performance

Exercise Number 1a

Help Tom develop his first asset register for the pump station using the data provided:

- Prologue
- Layout plans
- The Excel worksheets in your packet
- Your own knowledge and experience

Exercise Number 1a Cont.

Using a “Delphi” approach:

- Develop a “system process layout” for Tom
- Develop a register that you think is needed to manage the pump station
- Set the level of the maintenance managed item (“MMI”) to the level of hierarchy that you think is needed.

Q1: What is the State of My Assets?

Q1b: What condition is it in and what is its remaining physical life?

How do we assess condition ?

Why should we assess asset condition ?

What are the four major failure modes ?

What is the importance of “remaining useful life”?

How might we determine “remaining useful life”?

The 10-Step Asset Management Plan Process

System Layout; Data Hierarchy; Data Standards; Data Inventory
→ Inventory Assets

Condition Assess Protocol, Rating Methodologies
→ Assess Condition, Failure Modes

Expected Life Tables; Decay Curves
→ Determine Residual Life

Valuation; Life Cycle Costing
→ Determine Life Cycle Costs & Replacement $

Demand Analysis; Balanced Scorecard; Performance Metrics
→ Set Target LOS

Assign BRE Rating (Criticality)
← **FMECA; Business Risk Exp; Delphi Technique**

Determine Appropriate Maintenance
← **Root Cause; RCM; PdM; ORDM**

Determine Appropriate CIP
← **Confidence Level Rating; Strategic Validation; ORDM**

Fund Your Strategy
← **Asset Mgt Plan, Polices & Strategy; Annual Budget; Renewal Annuity**

Build the AMP
← **Asset Mgt Plan, Polices & Strategy, Annual Budget**

Management Engineering Environment GHD Clients People Performance

All Assets Deteriorate and Eventually Fail…

. . . How to minimize the total life-cycle cost of managing the failure process?

Sediment build-up increasingly restricts flow

Cleaning & relining adds 50 years life

Fundamental Principle

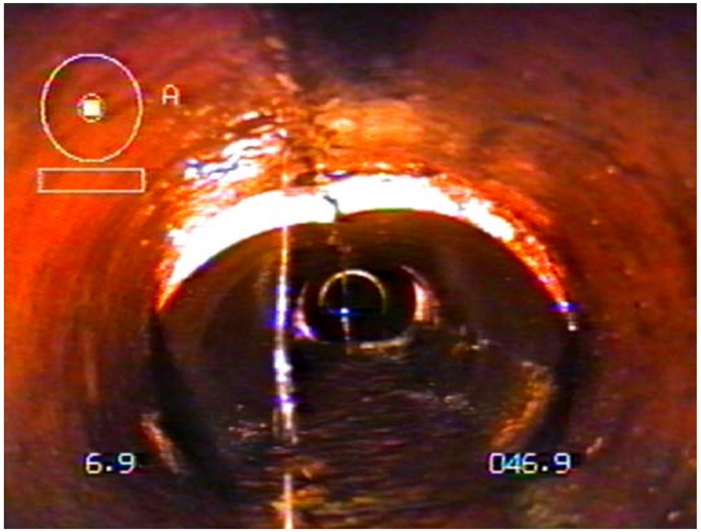
- Condition is important only to the extent that it provides insight into
  - The *nature* of possible failure
    - Its root cause
    - Its pattern (the shape of the "decay curve")
  - The likely *timing* of failure (residual functional life)

Typical Condition Assessment Techniques

1. Visual inspection
2. Non-destructive testing
3. Destructive testing

Evolution of Methods to Inventory and Document Structural Collection System Conditions:

- Smoke Testing
- Dye Testing
- Lamping
- Video Inspection (CCTV)
- Sonar
- Ground Penetrating Radar



Evolution of Technology: Alignment Inspection and Correction Data

- Coupling Failure
- Bearing Failure

Example: Early Forms of Condition Definitions and Ranking Criteria

Condition Class 1:	Damage to be repaired immediately
Condition Class 2:	Damage to be repaired within 1 year
Condition Class 3:	Damage to be repaired within 3 years
Condition Class 4:	Damage to be repaired within 7 years
Condition Class 5:	Damage to be repaired in the course of other construction work
Condition Class 6:	No damage

A. Urgent repairs
   - To meet emergency situations
   - To meet legal requirements

B. Necessary repairs
   - To eliminate safety hazards and code violations
   - To meet contractual obligations
   - To perform required renovations or repair

C. Desired repairs
   - To replace equipment
   - To extend or enhance service
   - To match funds

D. Ongoing repairs
   - To continue work in progress

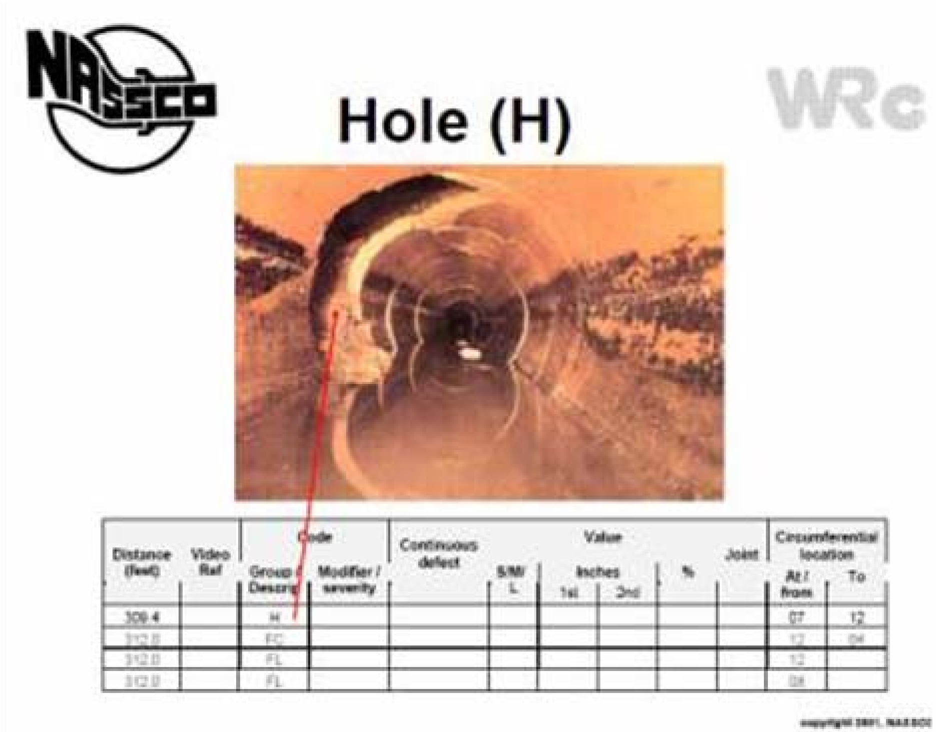
E. Deferrable repairs
   - To perform non-essential renovations/improvements
   - To perform projects with questionable need or with timing problems

"Single Dimensional"

Example: Evolving Collection System Rating Structure

- Pipe Rise/Joint Offset
  1. Minor – not critical
  2. Moderate – not critical to flow pattern
  3. Significant – possible infiltration source
  4. Severe – pipe offset impeded/obstructed flow, probable infiltration source
- Pipe Dip
  1. Length 0-10 feet – not critical
  2. Length 11-20 feet – causes minor velocity reductions
  3. Length 21-30 feet – causes solids to settle in pipe
  4. Length >31 feet – can cause significant solids buildup
- Joint Infiltration
  1. Slow drip
  2. Steady drip
  3. Continuous flow – moderate
  4. Continuous flow – severe
- Mineral Buildup (at joint)
  1. Deposit on wall without any noticeable flow restriction – not critical
  2. 0.25 Reduction in pipe diameter, some flow restriction
  3. 0.25-0.5 Reduction in pipe diameter, significant flow restriction
  4. >0.5 Reduction in pipe diameter, camera unable pass – severe flow Reduction
- Laterals with Roots (house lateral)
  1. Some root penetration – no blockage
  2. More established root presence – minimal blockage
  3. 0.5 of lateral is blocked – possible infiltration and flow restriction
  4. Near total blockage – probable infiltration and flow restriction
- Joints with Roots
  1. Some root penetration – no blockage
  2. More established root presence – minimal blockage
  3. 0.5 of pipe blocked – possible infiltration and flow restriction
  4. Near total blockage – probable infiltration and flow restriction
- Pipe Break
  1. Minor Break – no structural impairment
  2. Break with separation – structural impairment not immanent
  3. Break with separation/partial collapse immanent structural failure
  4. Severe breakage requiring immediate attention to maintain flow
- Debris Blocking Pipe
  1. Minor debris – minimal flow restriction
  2. Moderate debris – minor flow restriction
  3. Significant debris – moderate flow restriction
  4. Severe debris – near total flow restriction
- Pipe Cracks
  1. Hairline no structural impairment
  2. Crack with separation structural impairment not immanent
  3. Crack with separation/partial collapse immanent structural failure
  4. Severe crack requiring immediate attention to maintain flow
- Lateral protrusion
  1. <1" minimal flow restriction
  2. >1" moderate but not critical to flow pattern
  3. 0.5-0.75 full pipe blocked – severe flow restriction
  4. 0.75 full pipe blocked – severe flow restriction

Emergent “National” Standards - Pipes



“PACP” - Pipe Assessment Certification Program

*Structural defect scores - Pipe sewers

Defect	MSCC Code		Description	Score
Longitudinally	OJM		Medium < 1*pipe thickness	1
displaced joint /	OJL		Large > * pipe thickness	2
Open joint			If soil visible grade as a hole	165
Radially displaced joint	JDM		Medium < 1* pipe thickness	1
	JDL		Large > 1* pipe thickness	2
			> 10% diameter & soil visible	80
Cracked	CC		Circumferential	10
	CL		Longitudinal*	10
			Complex*	40
			Helical*	40
	CM			
Fractured	FC		Circumferential	40
	FL		Longitudinal*	40
			Complex*	80
			Helical*	80
	FM			
Broken	B			80
Hole	H		Radial extent <¼	80
			Radial extent ¼+	165
Collapsed	X			165

*Abstract from Sewerage Rehabilitation Manual (Fourth Edition)

National Association of Sewer Service Companies (NASSCO)
Water Research Centre (WRc), Manual of Defect Classification

Condition Assessment Protocols (CAP's)

Which assets? What information? *How used*?

CAP 1 - A simple scoring system e.g. good,fair,poor or 1-3 ,1-5 or 1-10

CAP 2 - A matrix scoring system with multiple distress factors and weightings to derive a score

CAP 3 - Use of sophisticated techniques to determine the "residual life to intervention" or end of physical life

Characteristics of a Good Condition Assessment Protocol

A good condition assessment protocol is:

- Focused on “remaining useful life” rather than just “good/fair/poor”
- Carefully defined
  - Written protocol
- Built around “business risk exposure” (critical assets)
- Consistently applied
  - Across time
  - Across “inspectors”
- Cost effective
  - Uses “smart data collection” techniques

Example: Condition Assessment Protocol 1

Condition Assessment CAP 1 (0 to 5)

Condition Rating	Description	Maintenance Level	Degree of Replacement
0	NEW	Normal	0%
1	PERFECT/EXCELLENT CONDITION	Normal	0%
2	MINOR DEFECTS ONLY	Minor	5%
3	BACKLOG MAINTENANCE REQUIRED	Significant	10-20%
4	REQUIRES MAJOR RENEWAL	Renew	20-40%
5	ASSET ALMOST UNSERVICEABLE	Replace	>50%

Condition Assessment Protocol “1.5”

Expanded 6 Point Scale

6 point Scale

0
1
2
3
4
5

4.1
4.3
4.5
4.7
4.9
5.0
5.1
5.2
5.3
5.4
5.5
5.6
5.7
5.8
5.9

Refine CAP Scale
To Fit
Relative Distress
Of Assets

Example: Condition Assessment Protocol 2

Multiple "Dimensions"

Distress Modes	Rating 1-5	Weighting*	Score
Corrosion	3	3	9
Vibration	1	1	1
Leakage	2	1	2
Heat	4	2	8
Performance	2	3	6
Noise	1	1	1
Condition Rating			27

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Example: Condition Assessment Protocol 3

Vibration Signature

Sonic Signature

Thermal Signature

Electrical Signature

Oil Residue Signature

Electro-magnetic Signature

Performance Signature

CITY OF PHOENIX - 24th STREET WATER TREATMENT PLANT

ASSET CONDITION RELIABILITY ASSESSMENT RATING TABLES

Conventional Pumps

Inclusion: Dry well & line shaft pumps   Dosing Pumps

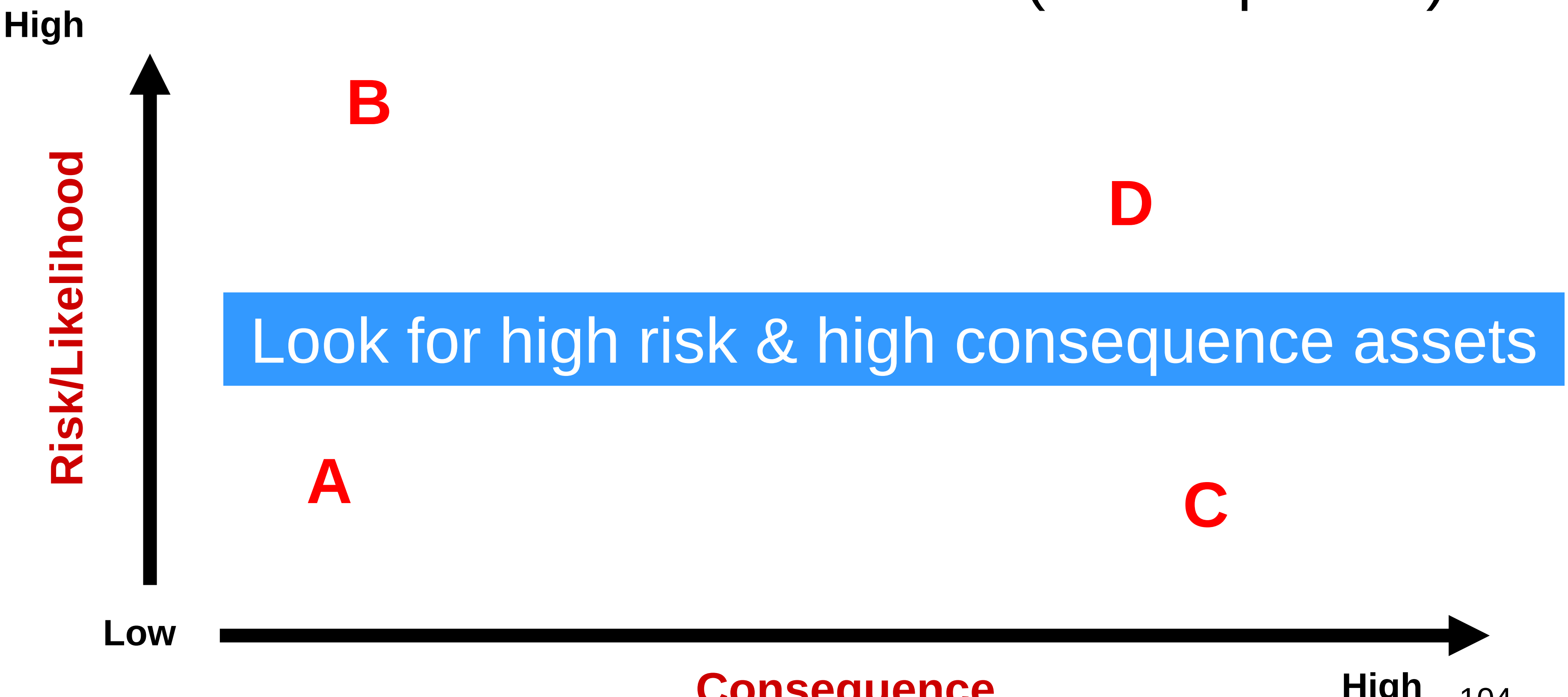
	Aspect	Distress Mode	Rating 1	Rating 2	Rating 3	Rating 4	Rating 5
			CONDITION ASSESSMENT				
A	Structure Appearance	Leakage	Appears as new.	Minimal moisture on seals/joints.	Water dripping from seals/joints.	Water pooling on floor	Water squirting/ running onto floor.
B		Shaft, Supports, Bearing Deterioration	Shaft & supports sound - no shaft distortion or deterioration evident.	Minor shaft/ support deterioration evident, no impact on the structural strength or function.	Shaft distortion or bearing/housing wear evident, little impact on structural integrity or function.	Shaft distortion or bearing/housing wear evident and has impacted on asset integrity or function.	Significant shaft distortion or bearing/housing wear evident, high probability of fracture or failure.
C	Use	Motor Hours Run	< 10,000	> 10,000	> 50,000	> 100,000	> 200,000
D	Symptoms	Vibration	No unusual vibration detectable	Minor vibration detected	Moderate vibration	Considerable vibration (wristwatch shakes)	Major vibration
E		Temperature	No unusual temperature detected	Minimal heat from casing using hand	Heat detected by hand	Heat detected by hand is uncomfortable	Heat too high to assess by hand
F		Noise	No unusual noises detected.	Slight whine/rattle detected.	Moderate whine/rattle detected, easily heard over pump noise.	Loud whine/rattle.	Disturbingly loud operation/vibrations.
			RELIABILITY ASSESSMENT				
A	Unplanned Outages	Avg No./Year	0 / Year	< 2 / Year	< 5 / Year	< 10 / Year	> 10 / Year
B	Efficiency	Flow Output	Flow within 5% of duty point.	Flow within 10% of duty point.	Flow within 20% of duty point.	Flow within 40% of duty point.	Flow > 40% of duty point.

Smart Data Collection

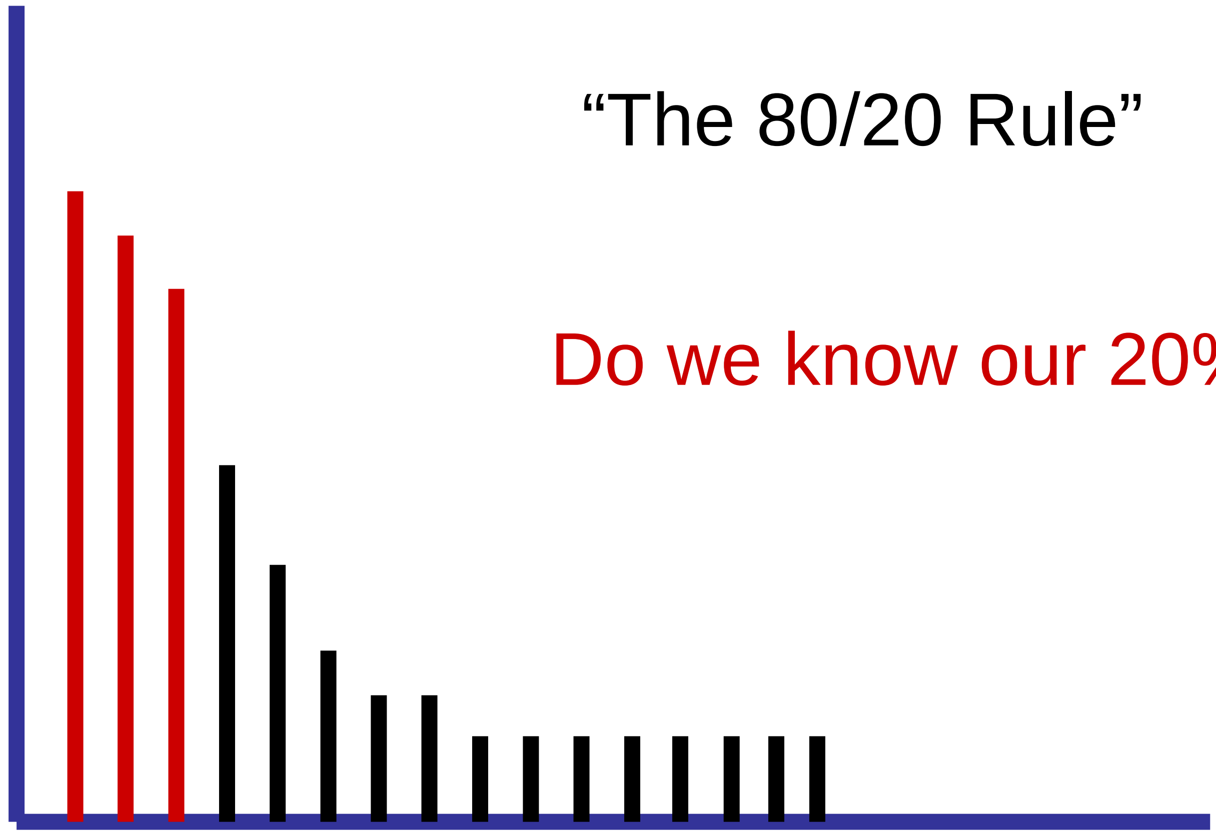
1. “Criticality” Driven (BRE)
   – Focus on high risk, high consequence assets first
2. “Pareto” Profiled
   – “20% of assets cause 80% of problems”
3. Sampling Approach
   – “Criticality based” sampling
   – Filtered levels of sophistication
4. Failure Mode Guided
   – Do I even need condition data?
5. “Root cause” (“Bayesian probability”) driven (SCRAPS)
6. Supplement with “Valued Judgment”/”Delphi” approach

1. Smart Data Collection:
"Criticality" Driven – Business Risk Exposure

- What is the likelihood of failure ? (risk)
- What is the cost of failure? (consequence)



2. Smart Data Collection:
"Pareto" Profiled – The "Trouble" Assets



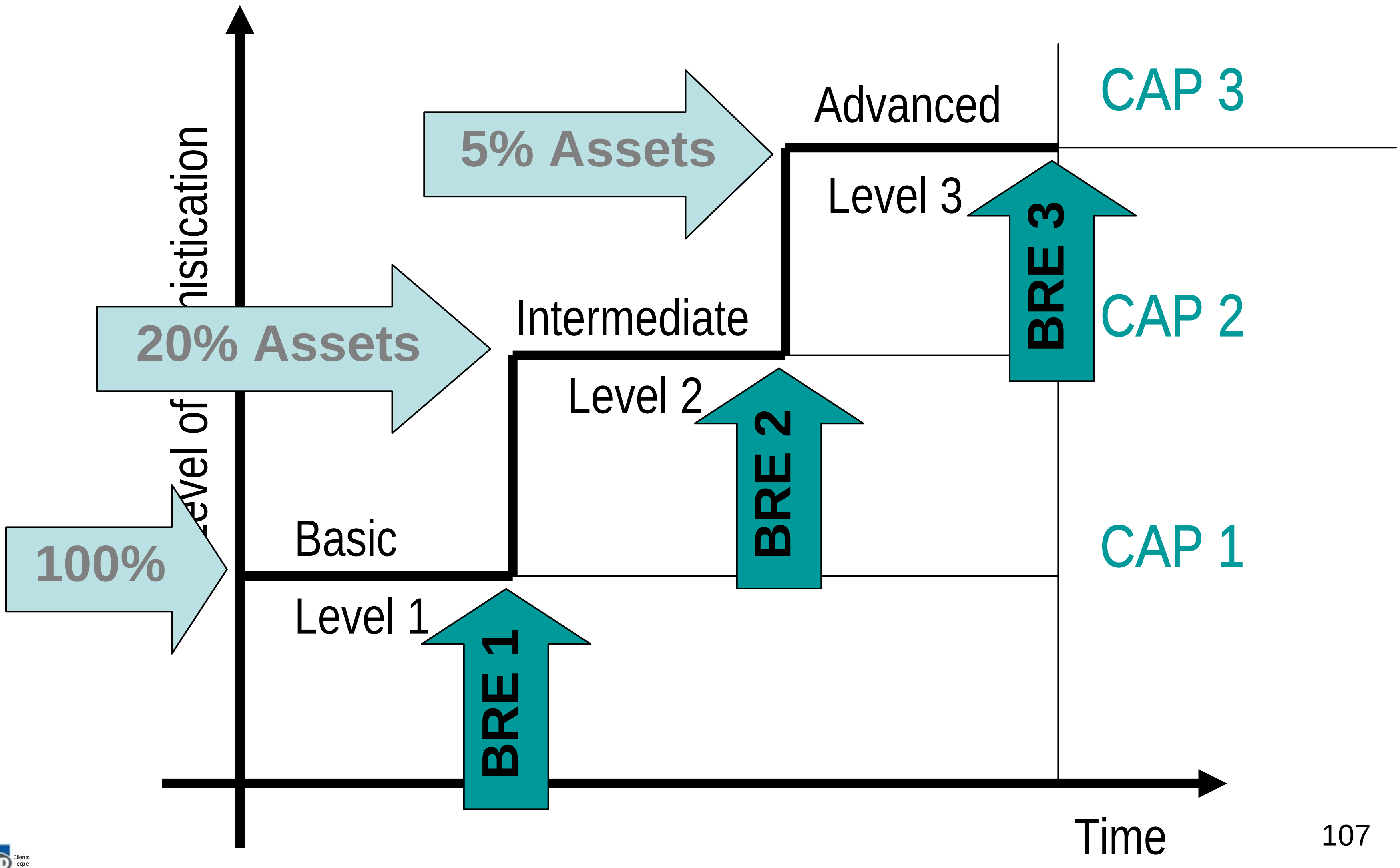
"The 80/20 Rule"

Do we know our 20%?

3a. Smart Data Collection: Stepped Sampling

– Valid statistically-based sampling can render virtually the same level of decision confidence at far less cost:
  - Use larger samples for more “critical” assets, smaller samples for less critical
  - Build samples around “root causes” of failure
    – Understand our failure modes!

3b. Smart Data Collection: A Stepped Approach to Filtering

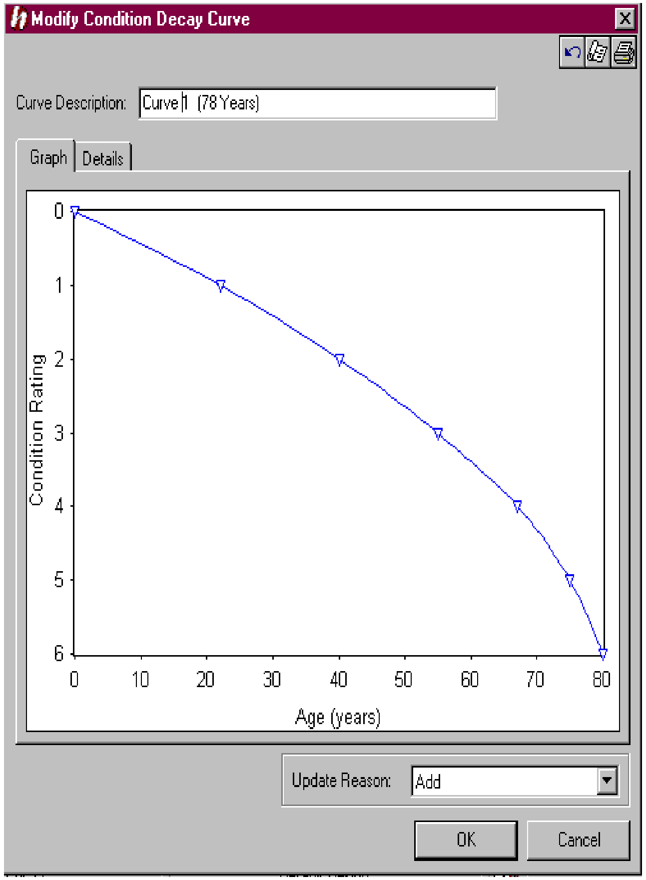


4. The Four Major Failure Modes

Mode	Definition	Tactical Aspects	Management Strategy
1. Capacity	Volume of demand exceeds design capacity	Growth, system expansion	Redesign
2. LOS	Functional requirements exceed design capability	Codes/permits: NPDES, CSOs, SSOs, OSHA, noise, odor, life safety; service, etc	Redesign
3. Mortality	Consumption of asset reduces performance below an acceptable minimum level	Physical deterioration due to age, usage (including operator error), acts of nature	O&M, Renewal
4. Efficiency	Performs ok, but cost of operation exceeds that of feasible alternatives	"Pay-back" period	Replace

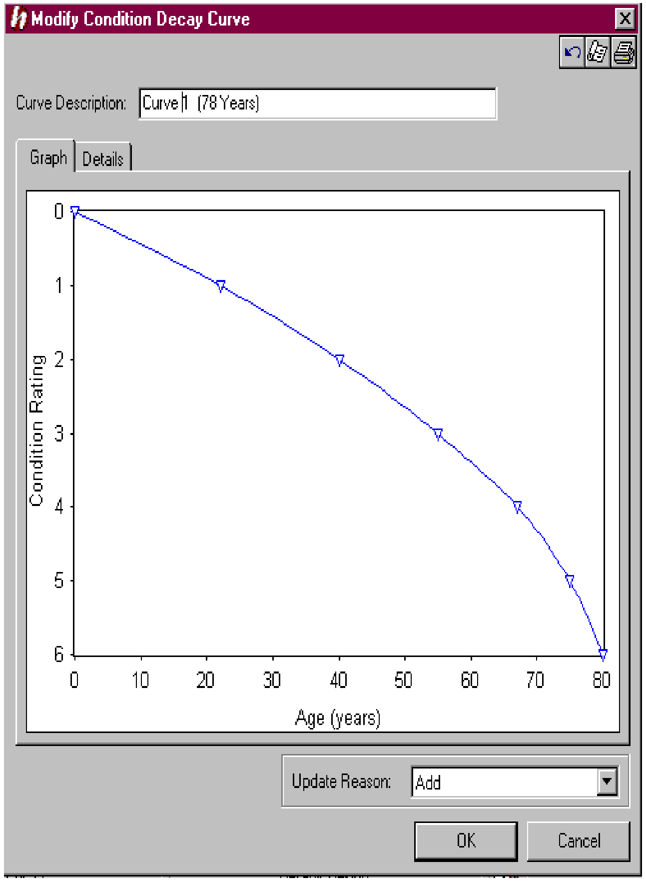
Condition and the "Decay Curve"

- Condition gives us insight as to:
  1. The shape and nature of the decay or failure curve
  2. Where the asset is currently on the decay curve
  3. A reasonable estimate of remaining useful life



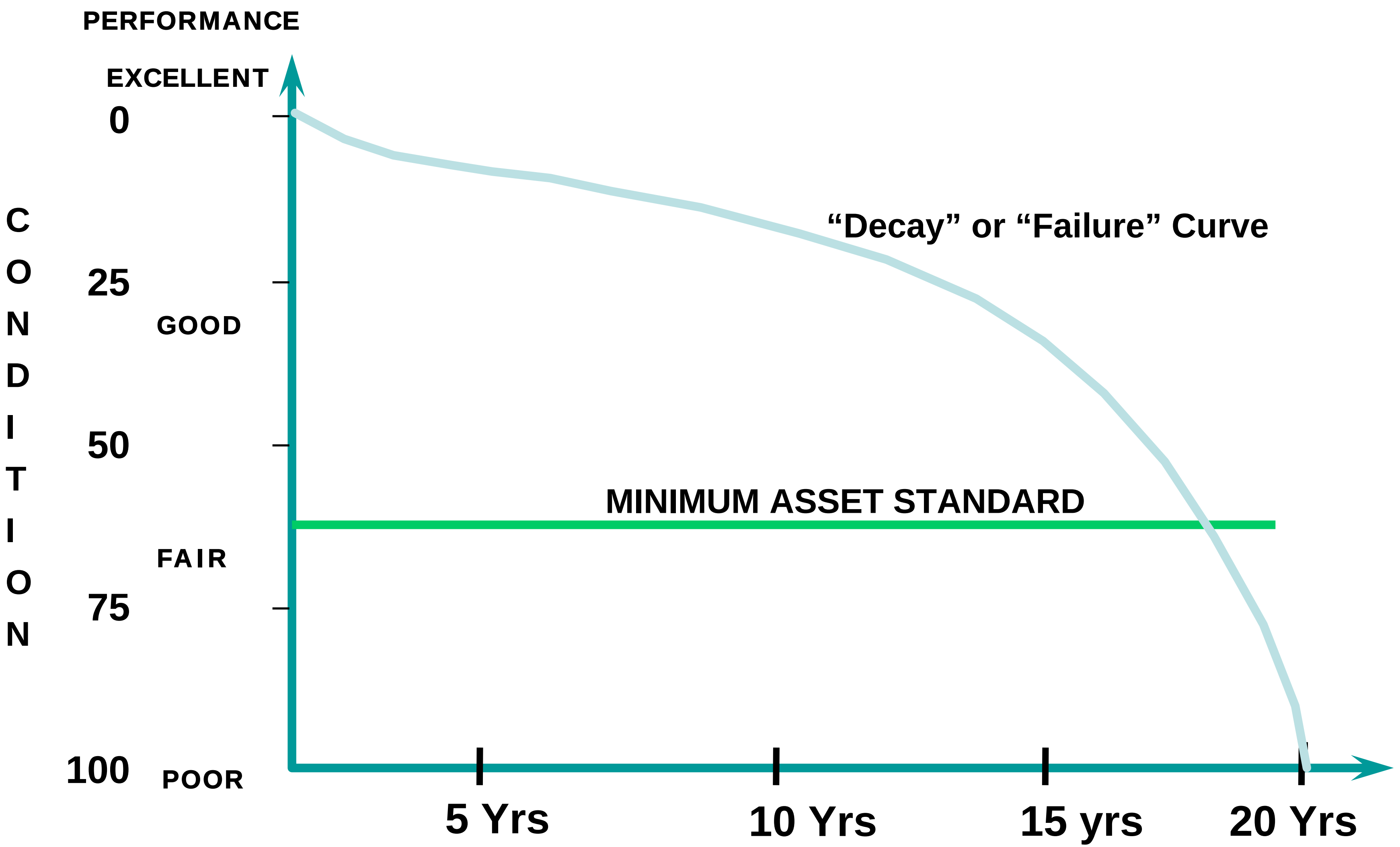
“Practically” Developing a Decay Curve

- “Longitudinal” data (“panel” study)
  - Systematically gathered condition data acquired year after year over the life of the same asset or set of assets
- “Latitudinal” data
  - Done one time where condition data is gathered for the same type of asset but of different ages (multiple assets)



“ Two data points are better than none; four better than two; ten better than four; etc”

Tying “Condition” to “Failure”



5. Smart Data Collection: "Bayesian" (Root Cause) Driven

- "Valued judgment" is used to assign failure variables and propositions (sequences of causes of failure)
- "Valued judgment" used to assign conditional probabilities (likelihood of occurrence)
- "Causal path" networks are developed relating "root cause" to functional failure
- Probabilities are assigned to each of the path elements

What is SCRAPS?

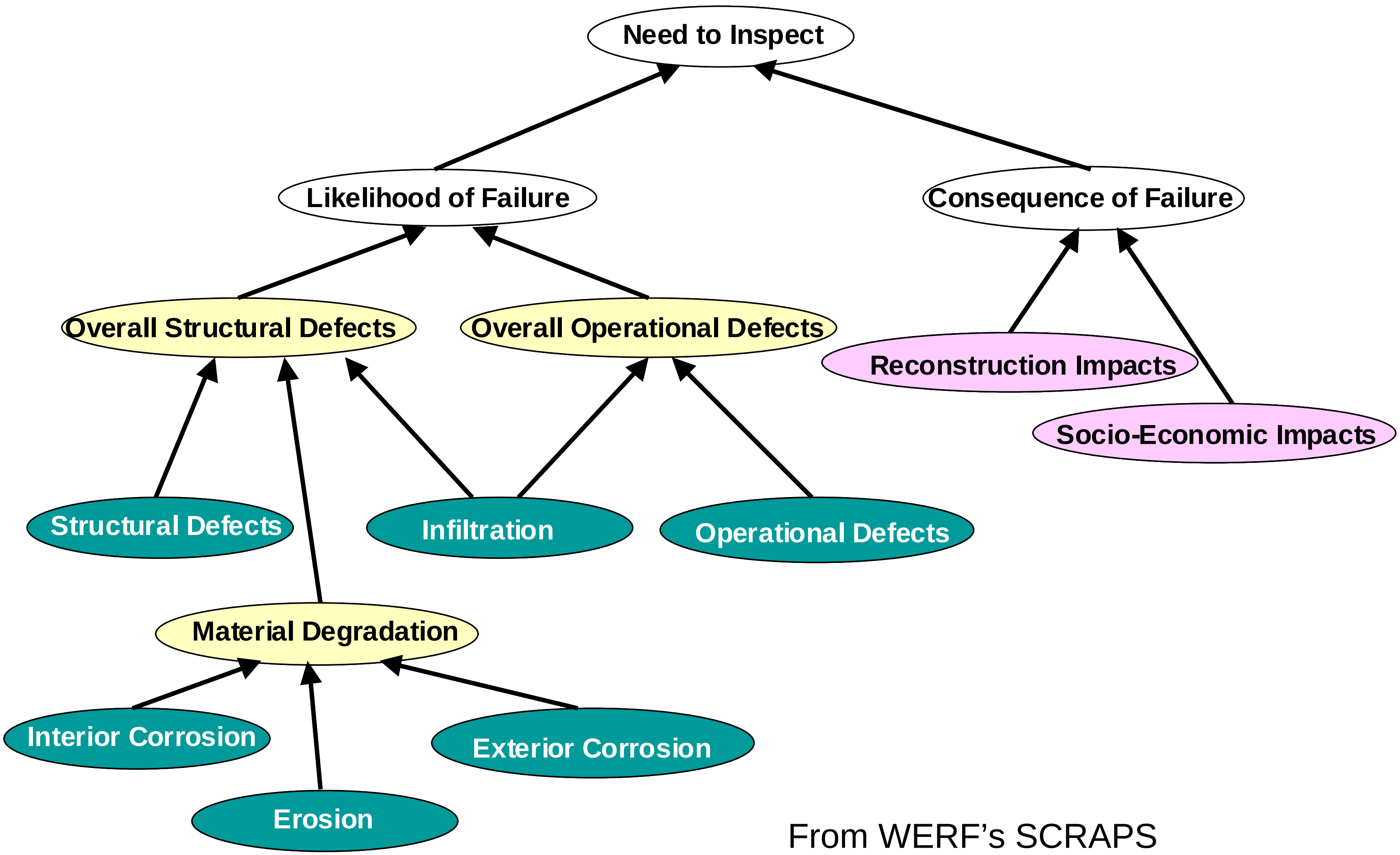
Sewer
Cataloging,
Retrieval
And
Prioritization
System

Courtesy WERF & Brown & Caldwell

Bayesian Probability Example

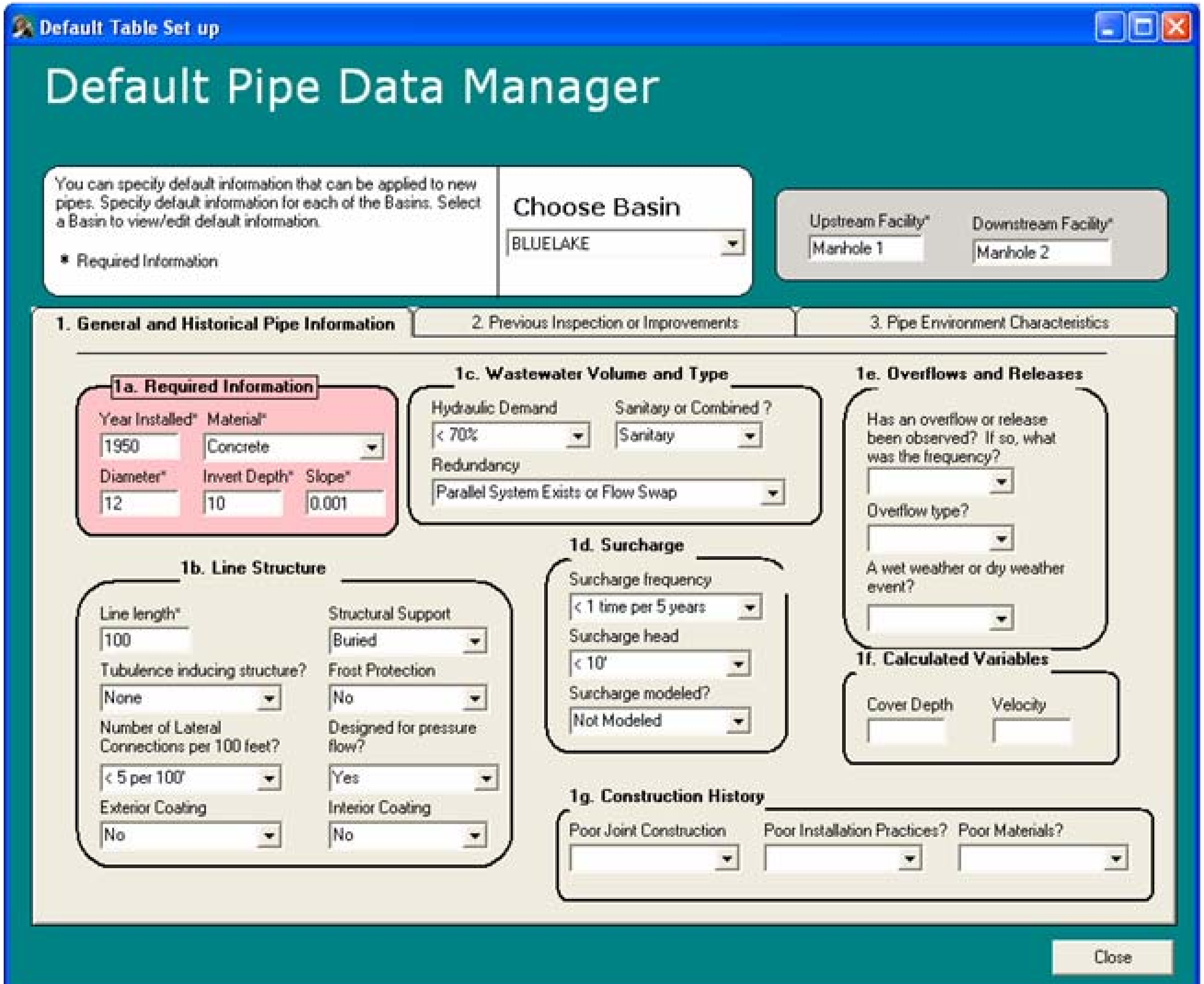
- *Proposition*: Sewer joint failures are common when the sewer is in marshy soil without support
- Or
  - If probability of marshy soil = High
  - And probability of sufficient support = Low
  - Then P(Joint Failure) = High

SCRAPS' Bayesian "Logic Structure"

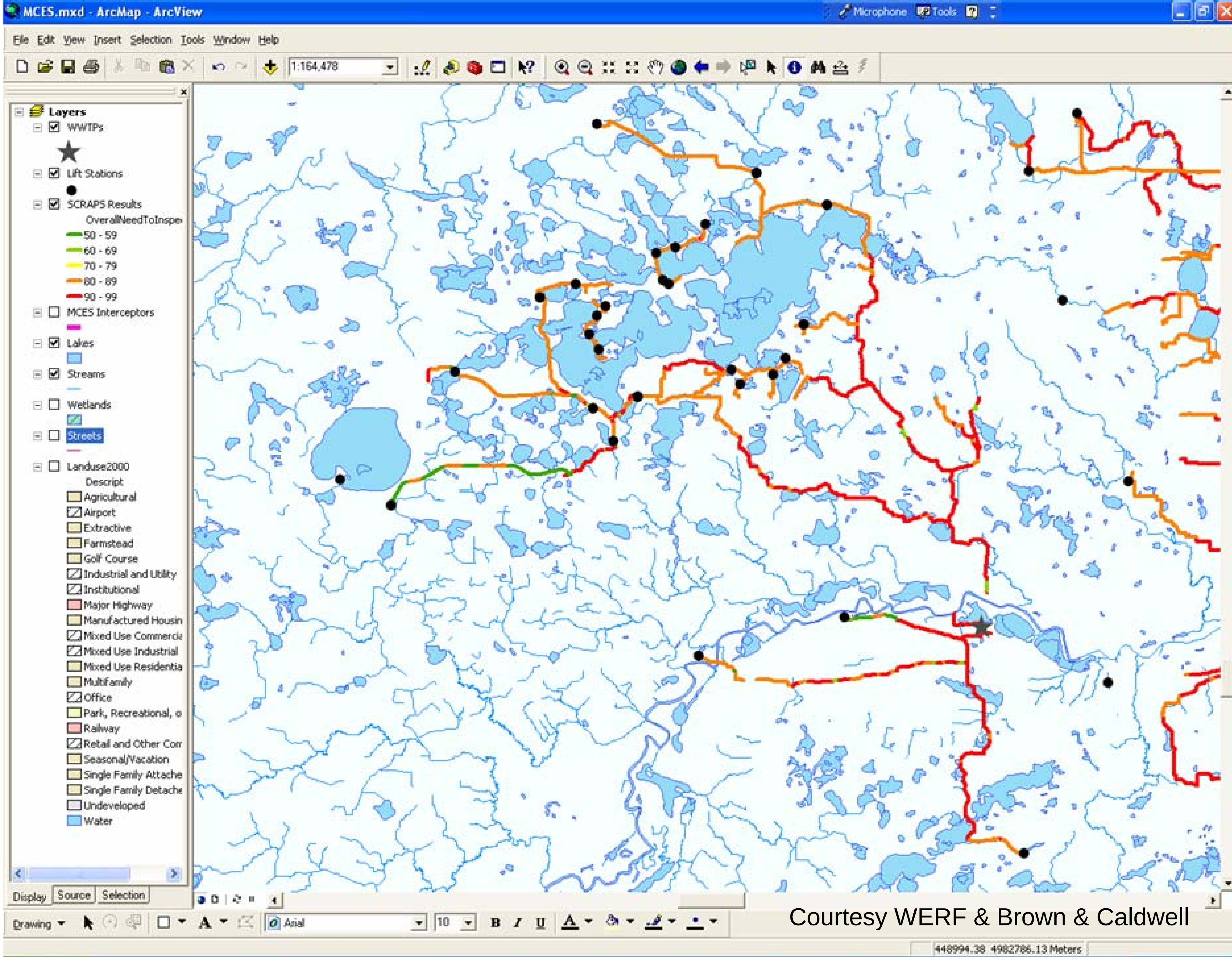


From WERF's SCRAPS
Developed by Brown & Caldwell

Default Data Manager



Courtesy WERF & Brown & Caldwell



Courtesy WERF & Brown & Caldwell

Determining "Remaining Useful Life"

- Level 1
  - Effective Life Table
- Level 2
  - Effective Life Table + Modification Factors
- Level 3
  - Direct observation Tables
- Level 4
  - Condition/decay-curve Based Tables

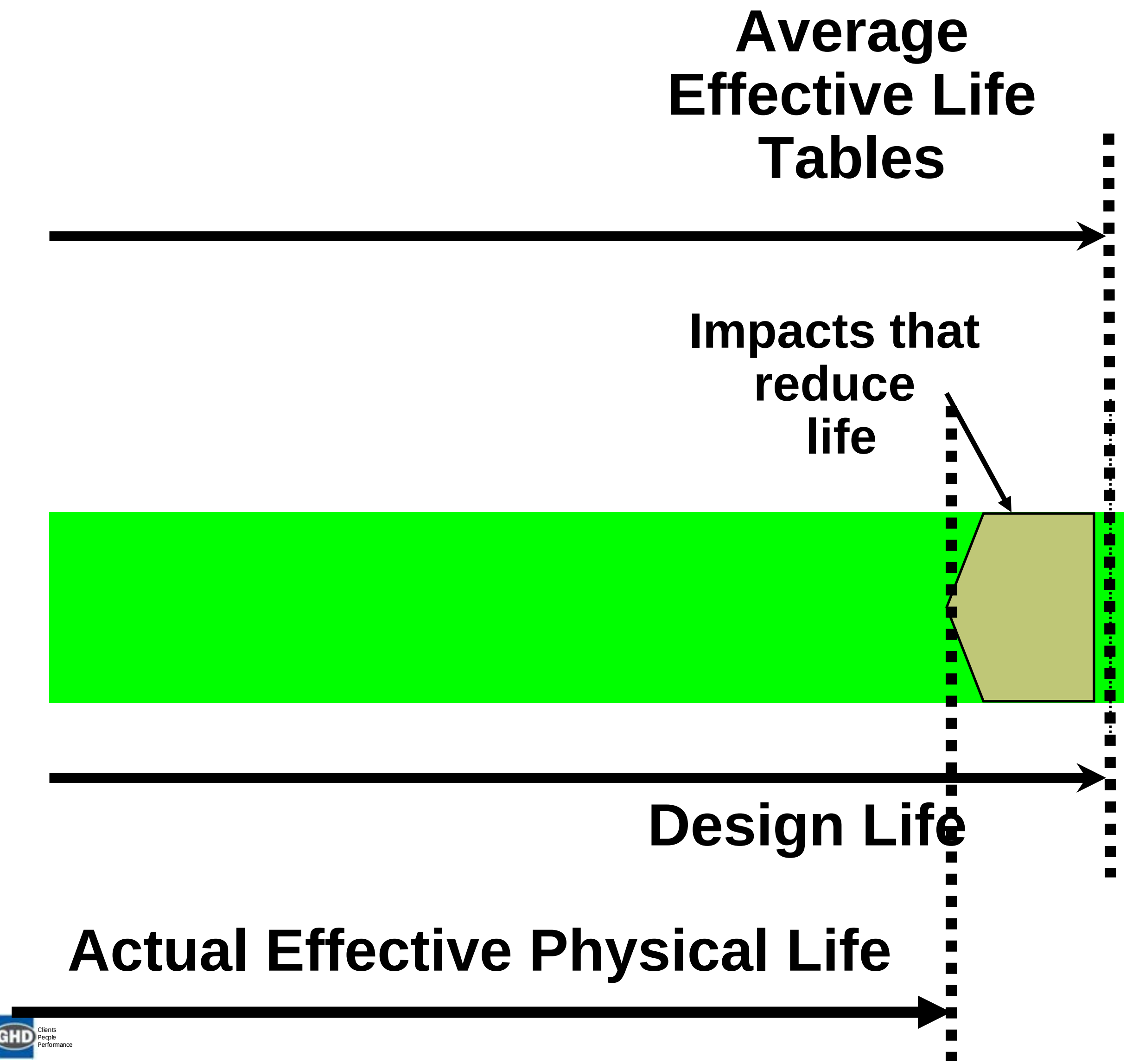
The "Table of Effective Lives" Approach

- Sources:
  - Manufacturers
  - Industry Associations
  - GASB
  - Colleagues
  - Consultant Engineers
  - Research
    - Professional associations
    - Universities
  - International community

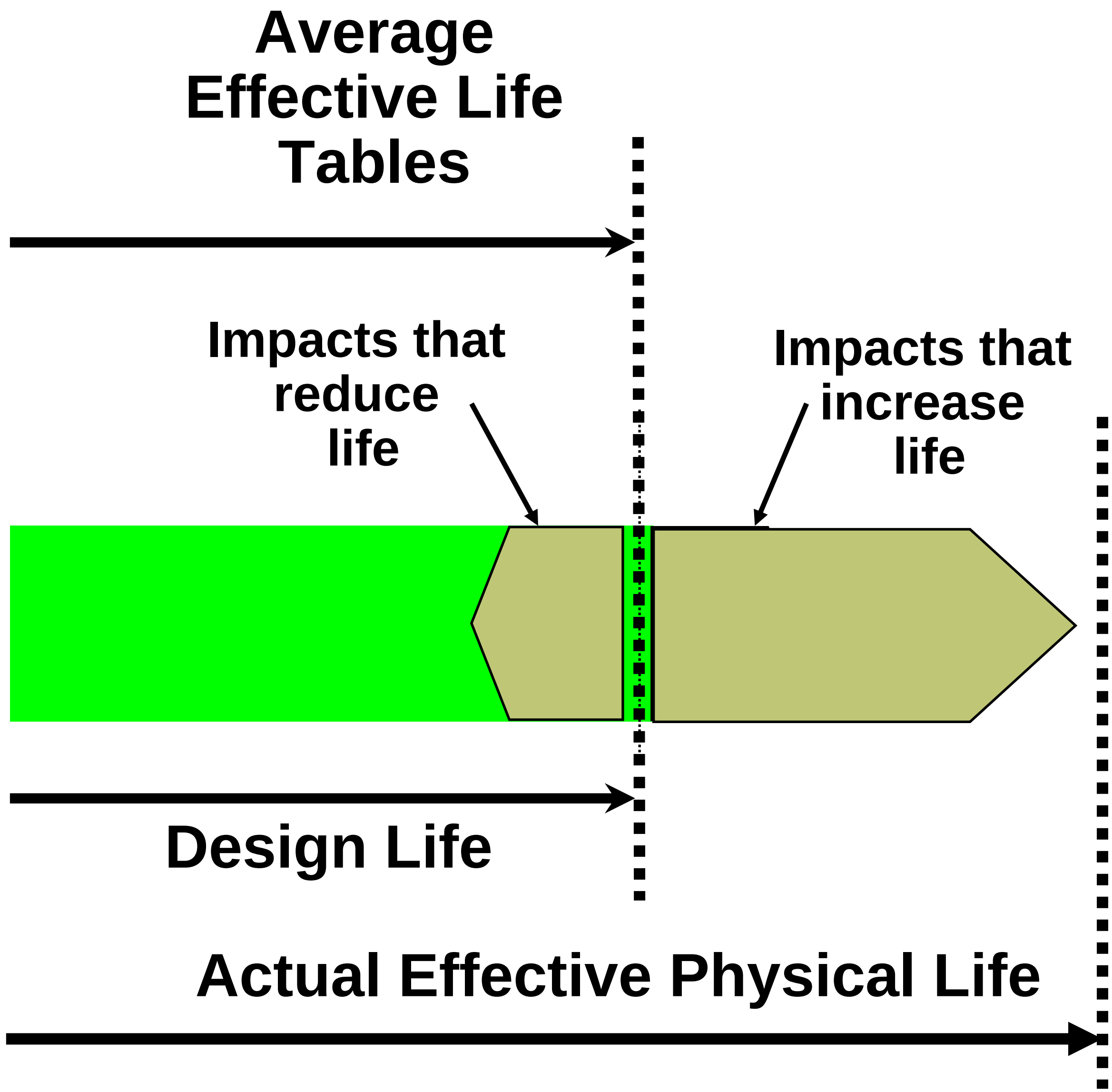
Effective Lives (Years)

Class	Asset Type	Effective Lives
1	Civil	75
2	Pressure Pipework	60
3	Sewers	100
4	Pumps	40
5	Valves	30
6	Motors	35
7	Electrical	30
8	Controls	25
9	Building Assets	30
10	Land	300

Amending Standard Effective Lives



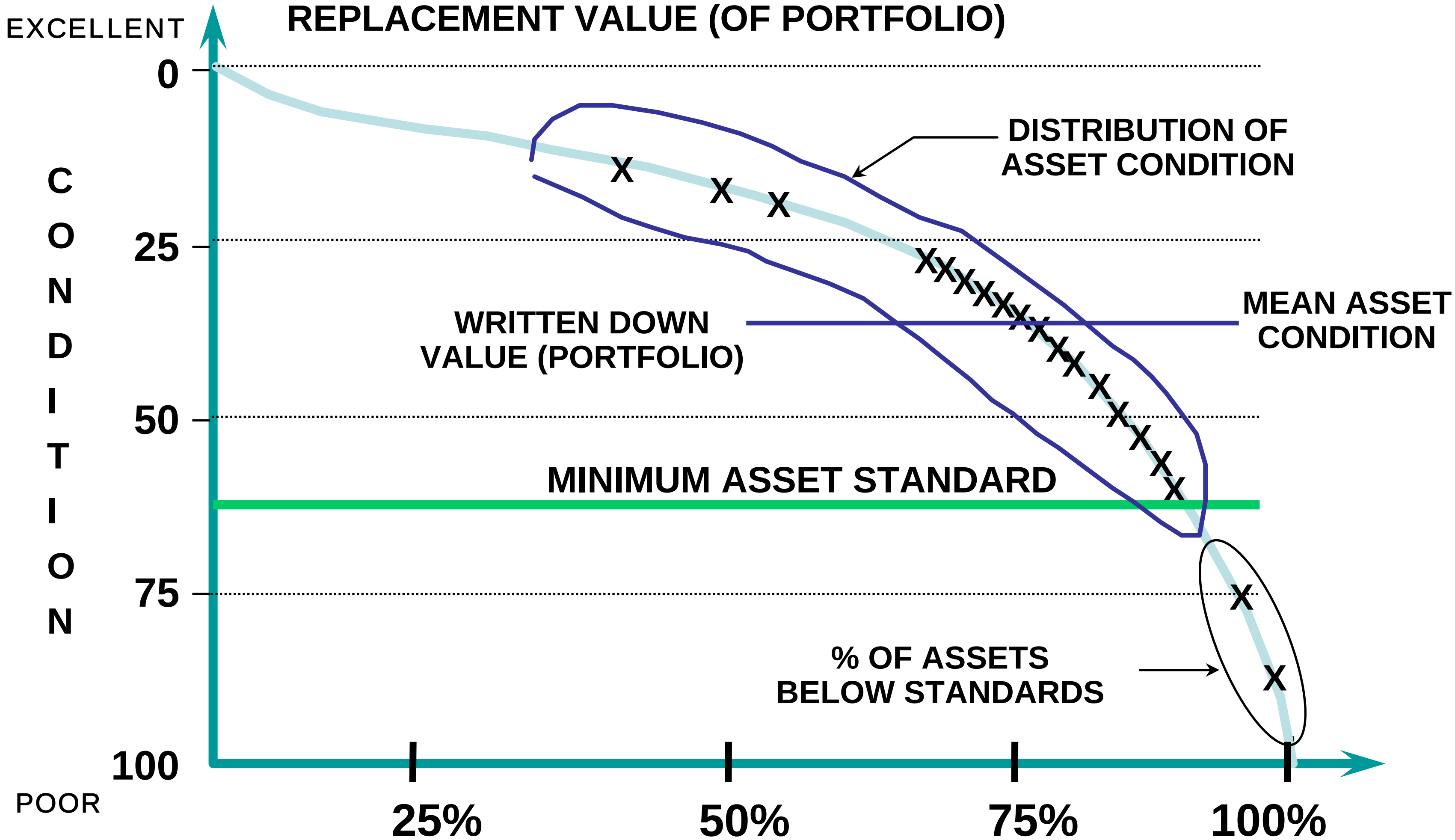
Amending Standard Effective Lives



Level 2 - 3
Standard Effective Life Variation Factor Matrix

FACTORS	IMPACT RATING FACTORS				
	1	2	3	4	5
1 DESIGN STANDARDS	+10%	+ 5%	0%	- 5%	-10%
2 CONSTRUCTION QUAL.	+10%	+ 5%	0%	- 5%	-10%
3 MATERIAL QUALITY	+10%	+ 5%	0%	- 5%	-10%
4 OPERATIONAL HISTORY	+10%	+ 5%	0%	- 5%	-10%
5 MAINTENANCE HISTORY	+10%	+ 5%	0%	- 5%	-10%
6 OPERATING ENVIRONM.	+10%	+ 5%	0%	- 5%	-10%
7 EXTERNAL STRESSES	+10%	+ 5%	0%	- 5%	-10%

The “% of Effective Life Consumed” Concept



% of Effective Life Consumed

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Condition-Based Conversion Table Approach

Effective Lives (Years)

Asset Type	Effective Lives	Condition Rating / Residual Life 1	2	3	4	5
Civil	75	75	60	45	30	15
Pressure Pipework	60	60	48	36	24	12
Sewers	100	100	80	60	40	20
Pumps	40	40	32	24	16	8
Motors	35	35	28	21	14	7
Electrical	30	30	24	18	12	6
Controls	25	25	20	15	10	5
Building Assets	60	60	48	36	24	12

These relationships may be linear or non-linear

Level 3 – Condition to Residual Life Table

Conditon - Residual Life Factors		**Condition/Residual Life**									
Asset Type	**Effective Lives**	1	2	3	4	5	6	7	8	9	10
Motor bearing		0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Bearing temp sensor		0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Cooling motor		0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Electric motor		0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Coupling		0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Blower bearing		0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Centrifugal blower		0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Front blower bearing		0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Discharge check valve		0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Input butterfly valve		0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Silencer		0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0

Condition Based Effective Lives		**Condition/Residual Life**									
Asset Type	**Effective Lives**	1	2	3	4	5	6	7	8	9	10
Motor bearing	25	22.5	20	17.5	15	12.5	10	7.5	5	2.5	0
Bearing temp sensor	20	18	16	14	12	10	8	6	4	2	0
Cooling motor	40	36	32	28	24	20	16	12	8	4	0
Electric motor	75	67.5	60	52.5	45	37.5	30	22.5	15	7.5	0
Coupling	15	13.5	12	10.5	9	7.5	6	4.5	3	1.5	0
Blower bearing	25	22.5	20	17.5	15	12.5	10	7.5	5	2.5	0
Centrifugal blower	75	67.5	60	52.5	45	37.5	30	22.5	15	7.5	0
Front blower bearing	25	22.5	20	17.5	15	12.5	10	7.5	5	2.5	0
Discharge check valve	25	22.5	20	17.5	15	12.5	10	7.5	5	2.5	0
Input butterfly valve	25	22.5	20	17.5	15	12.5	10	7.5	5	2.5	0
Silencer	75	67.5	60	52.5	45	37.5	30	22.5	15	7.5	0

Note!

- Condition assessment is not an end in itself, but is a *means* to an end
- The “end” is to determine “remaining useful life”
- “Good”, “Fair”, “Poor” type ratings have little utility unless they lead to an effective estimate of remaining useful life

The remaining useful life of an asset is what we have left to try to manage

Sheet B on the Exercise Spreadsheet

Effective Lives (Years)

Asset Type	Effective Lives
Civil	75
Pressure Pipework	60
Sewers	100
Pumps	40
Motors	35
Electrical	30
Controls	25
Building Assets	60

This is calculated based on class of asset you assign – you need to modify if it is not a reasonable estimate

Sheet B on the Exercise Spreadsheet

Effective Lives (Years)		Condition Rating / Residual Life				
Asset Type	**Effective Lives**	1	2	3	4	5
Civil	75	75	60	45	30	15
Pressure Pipework	60	60	48	36	24	12
Sewers	100	100	80	60	40	20
Pumps	40	40	32	24	16	8
Motors	35	35	28	21	14	7
Electrical	30	30	24	18	12	6
Controls	25	25	20	15	10	5
Building Assets	60	60	48	36	24	12

This is calculated – you only have to rate condition

Exercise Number 1b

Help Tom develop an understanding of the physical condition of the assets and components in the pump station :

- Use your asset register
- First, let's add data about the date the assets were acquired and a "best estimate" of their original cost (in current $)

Exercise Number 1b

- Now help Tom develop an understanding of the physical condition of the assets and components in the pump station :
  - Use your asset register
  - Set the "Base Effective Life" using Tab A
  - Identify an initial "Major Failure Mode"
  - Rate the condition using the condition assessment table (Tab B)
  - Set the appropriate Base Life Adjustment Factor (Tab A)
- The spreadsheet will then calculate
  - the Adjusted Expected Life,
  - an estimate of the Residual Life, and
  - the % of the asset that has been consumed

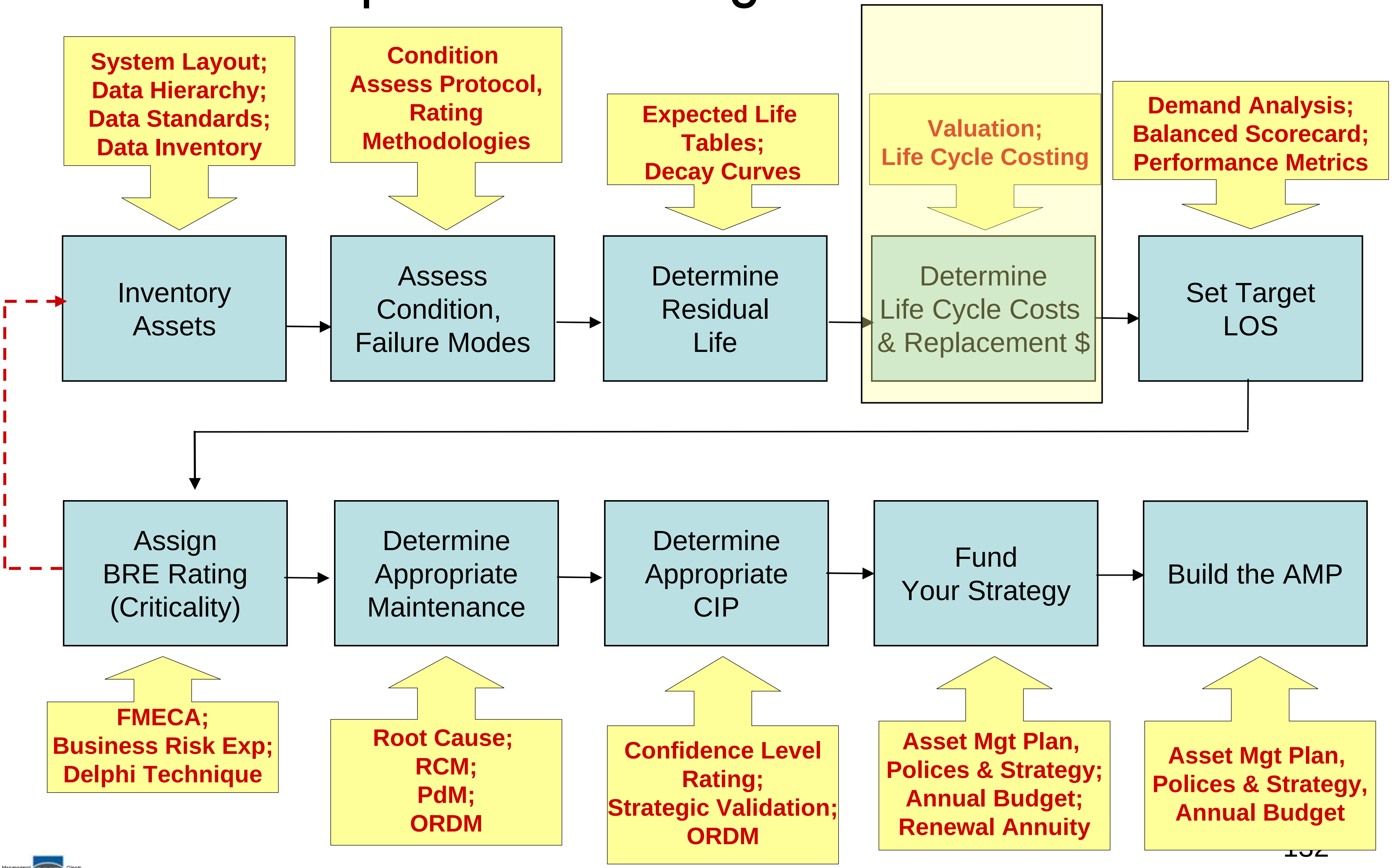
Q1: What is the State of My Assets?

Q1c: What is the value of my assets?

Why is “value” important?

How is “value” determined?

The 10-Step Asset Management Plan Process



Definitions – "Cost"

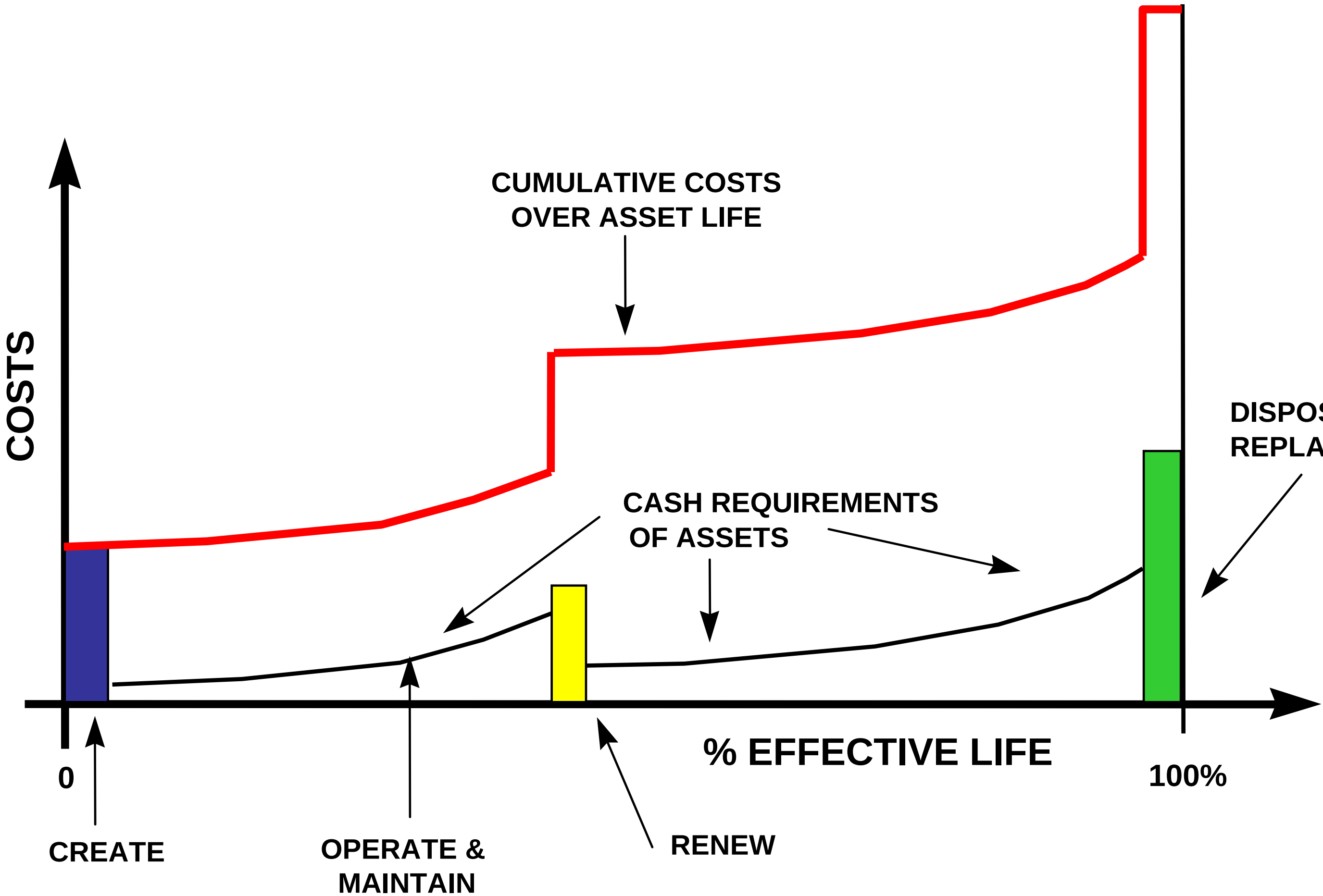
- **Cost -** The direct and indirect impact (specifically negative impact) of an activity, including money, time, labor, disruption, goodwill, political and intangible items.
- **Capital Cost -** The cost associated with the development of a project, including site acquisition, design, construction, interim financing, and project management or the cost incurred by the agency in procuring additional or upgraded assets.
- **Cost-In-Use -** The cost of ownership including operating, maintenance, cleaning, alterations, replacement and support costs.
- **Current Cost -** The cost of an asset measured by reference to the lowest cost at which the gross future economic benefits embodied in the asset could currently be obtained in the normal course of business.
- **Current Replacement Cost -** The cost of the future economic benefits expected to be derived from use of the asset, estimated as the current cost of the future economic benefits of the most appropriate replacement facility.
- **Current Reproduction Cost -** The current cost of reproducing (replicating) the asset in terms of both scale and technology.
- **Estimated Total Cost** - All costs of a capital nature that are required to bring a project to completion. Costs include planning, construction, land and equipment. Does not include operating costs, staffing costs and the cost of maintenance and refurbishment that are included in whole of life costs.
- **Life Cycle Cost -** The total cost of an item throughout its life, including the costs of planning, design, acquisition, operations, maintenance, and disposal, less any residual value, or the total cost of providing, owning, and maintaining a building or component over a predetermined evaluation period.
- **Recurrent Costs** - All costs, including the cost of finance, incurred in holding and operating an asset. Source:
- **Whole-of-Life Costs** - All costs involved in a project including the capital costs (planning, construction, land and equipment) and the operating costs (staffing costs and the costs of maintenance and refurbishment).

AAM's Two Major Cost "Perspectives"

- Direct Life Cycle Costs
  - Acquisition
  - Operation
  - Maintenance
  - Renew
    - Repair
    - Rehabilitate
    - Replace
  - Dispose/Decommission

- "Economic" Costs
  - Financial Costs
    - Direct Costs to the Government Organization
    - Direct Customer Costs
    - Community Costs
  - "Triple Bottom Line"
    - Financial/economic
    - Social
    - Environmental

The Nature of Life-Cycle Costs



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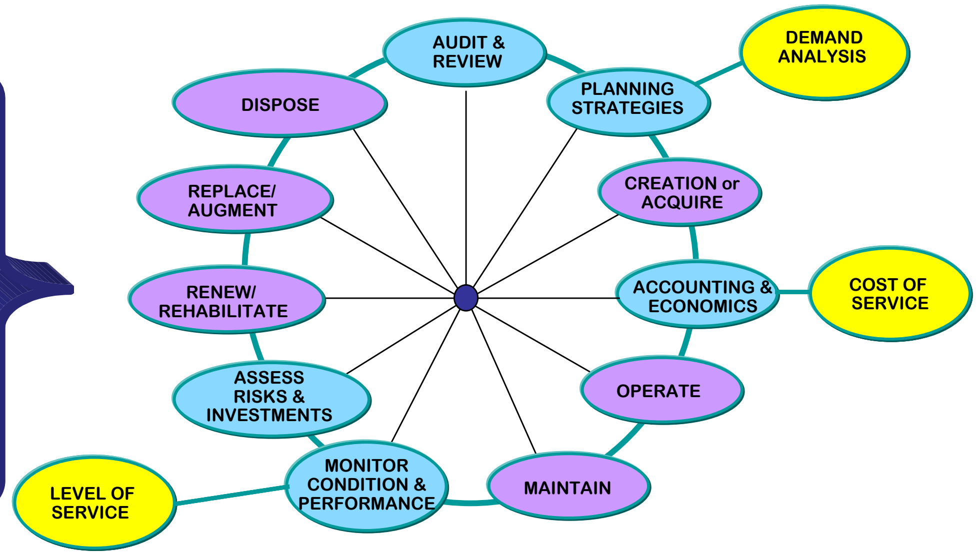
Defining Life Cycle Costs

Life Cycle Cost = (Original cost – salvage value) + operating costs + maintenance costs + rehab costs + decommissioning costs

Determining Life Cycle Costs

Direct Costs:
- Labor
- Supplies
- Equipment

Indirect Costs:
- Departmental
- Organizational
- Depreciation

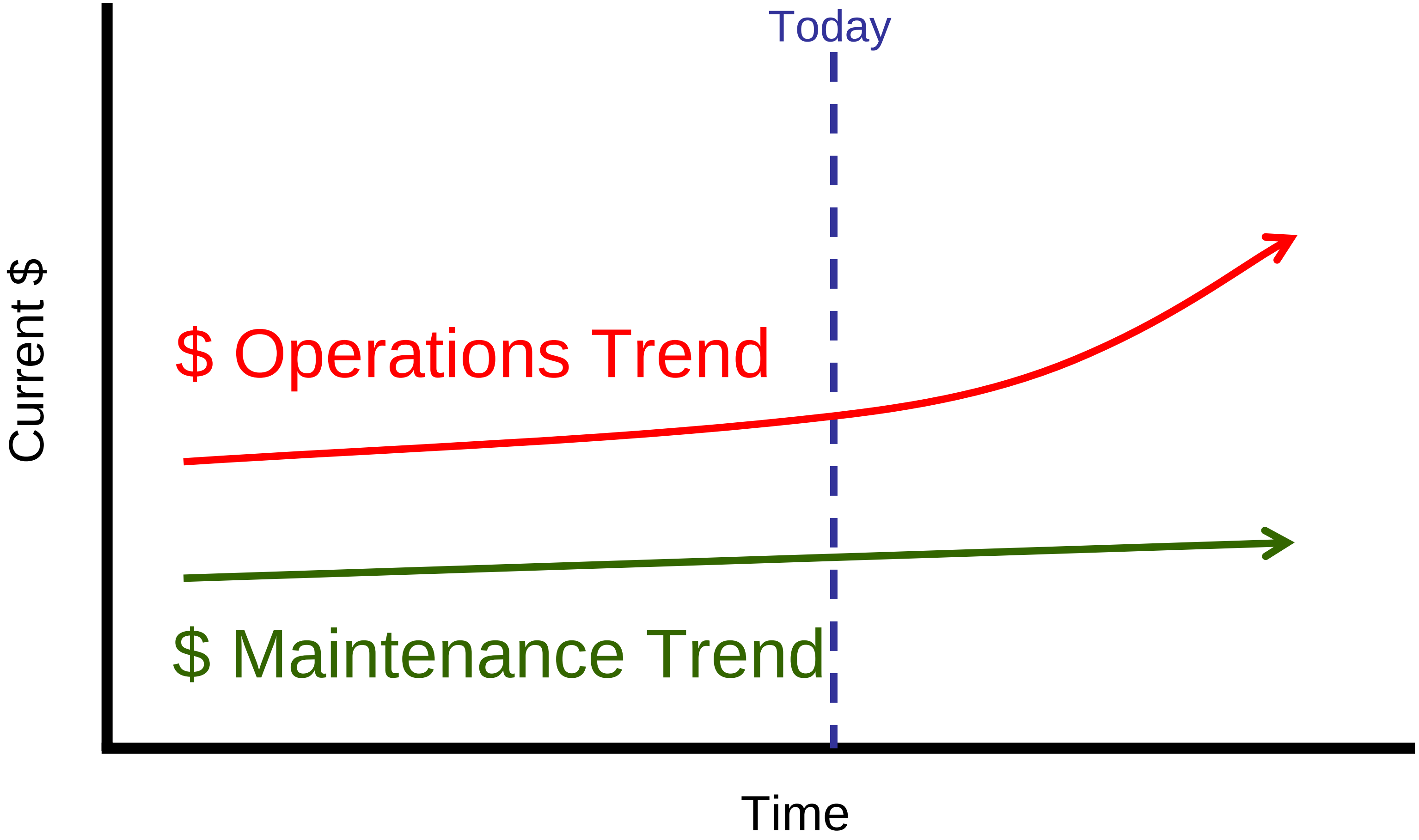


1. Cost Tracking
   – CMMS integrated to financial system
   – Activity Based Accounting set up
   – Storage over time

2. Cost Allocation

Primary Cost Unit	Minor code	Number of Units	$/Unit	Allocated Cost
Direct Labor				
	Direct Pay	2.5 hours	$42.00	$105.00
	Overhead	.5 hours	$6.00	$3.00
	Benefit Burden	1	$8.20	$8.20
	FICA, etc	1	$2.20	$2.20
Materials				
	Vehicle	1.5 hours	$47.15	$70.73
	Pipe	160 feet 8" PVC	$1.20/foot	$ 192.00

Life Cycle Costing – It's About Understanding *Drivers &Trends!*



Measuring “Full Economic Costs”

I. Direct Costs to the Local Government

1. Repair and return to service costs
2. Service outage mitigation costs
3. Utility emergency response costs
4. Public safety costs
5. Admin & legal costs of damage settlements
6. (Lost product costs)

II. Direct Customer Costs

1. Property damage costs (including restoration of business)
2. Service outage costs
3. Service outage mitigation and substitution costs
4. Access impairment and travel delay costs
5. Health damages

III. Community Costs

1. Emotional strain/welfare
2. Environmental Pollution, erosion, sedimentation
3. Destruction of/damage to habitat
4. “Attractability” (tourist, economic)

Definitions – “Value”

- **Condition Based Value** - The current value of the asset, generally measured as the replacement cost less the monetary value associated with the actual deterioration of its condition.
- **Current Market Value** - The amount for which an asset could be exchanged, or a liability settled, between knowledgeable, willing parties in an arm’s length transaction.
- **Current Value** - The value of an asset at the present time. It may be estimated from the current market value or where the market is deficient, by other methods such as depreciated value using current cost accounting.
- **Depreciated Value (“Book Value”)** – Value of an asset as determined using Generally Accepted Accounting Principles and as reflected on the balance sheet.
- **Deprival Value** - The direct and indirect loss which might be incurred by an organization if it were deprived of an asset; it assumes replacement of that which needs to be replaced rather than that which presently exists, hence factoring in current utilization of the asset.
- **Disposal Value** - See “Net Market Value” below.
- **Insurance Value** - The value on which insurance premiums are based.
- **Net Market Value** - The amount that could be expected to be received from the disposal of an asset in an orderly market after deducting costs expected to be incurred when realizing the proceeds of the disposal.
- **Replacement Value** – The current cost to substitute an entire asset with a new or equivalent asset without enhancement of capabilities.
- **Residual Value** - The net amount expected to be recovered on disposal of a depreciable asset at the end of its useful life.

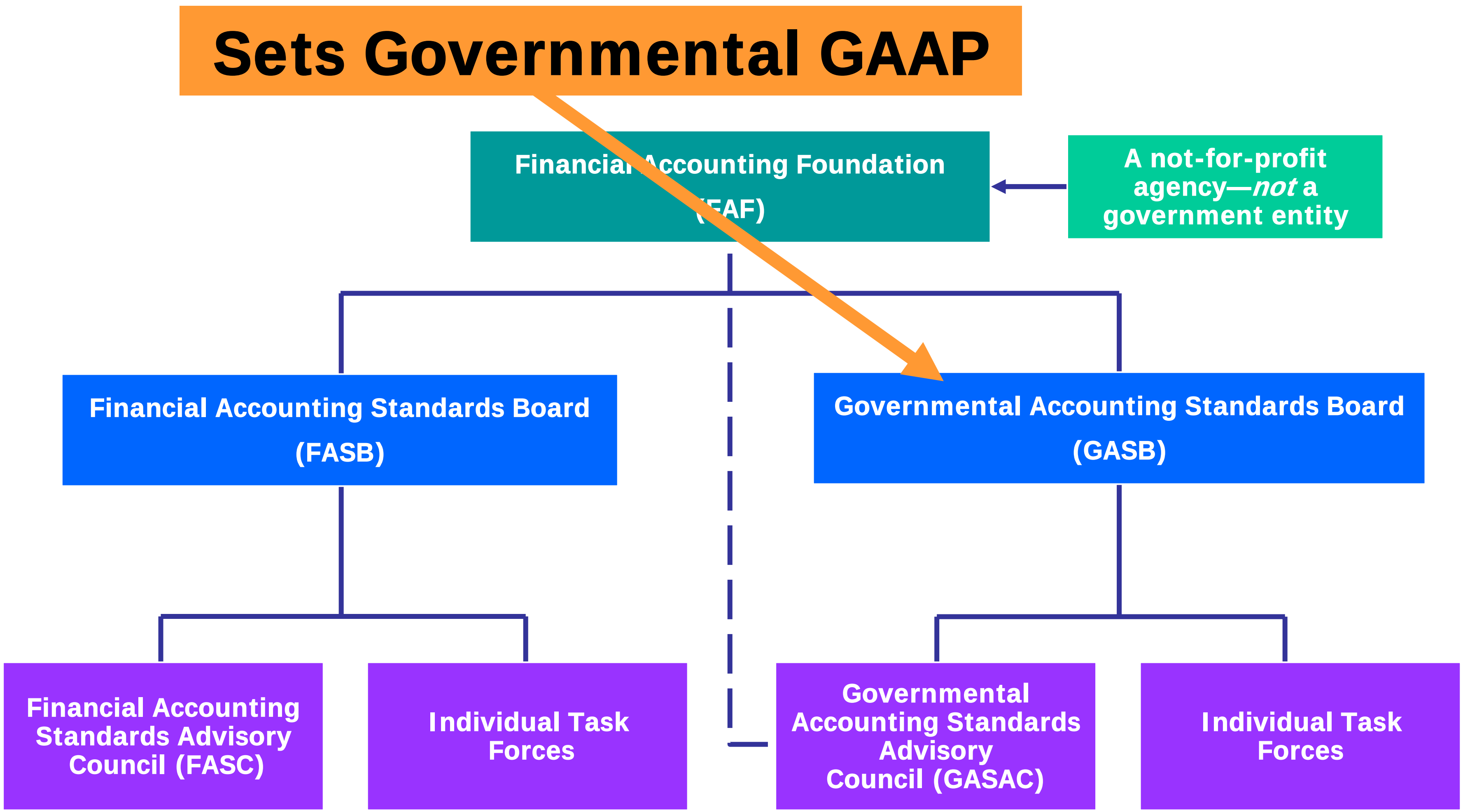
The Valuation Perspective

- Macro view
  - Financials
  - GASB
- Micro view
  - Life-cycle cost
  - Economic life
  - Optimal Renewal Decision Making

Aggregation of all assets

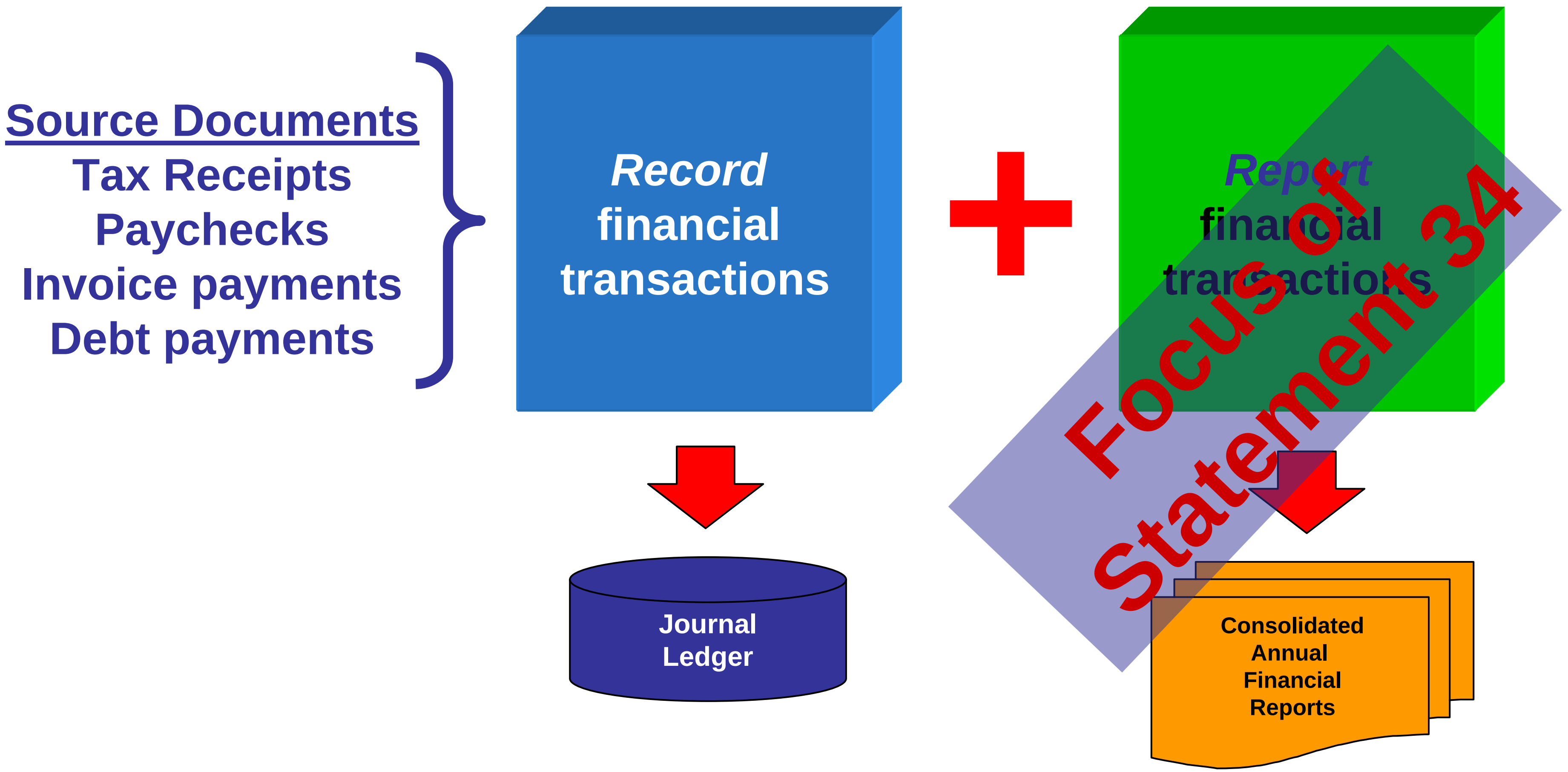
The individual asset

GASB - How GAAP is Set



What GAAP Is All About

Practices And Procedures By Which Governments:



What It's All About: the Financial Perspective

Wealth (Snapshot)	"Profit" (Revenue less expenses over specific period of time)	Cash Flow (Over specific period of time)

What is the Story to Be Told? – "Disclosure" & "Financial Condition"

- Financial condition – a government's ability to provide services as committed and to meet obligations as they fall due:
  - A. Liquidity
  - B. Solvency
    1. Cash solvency – the capacity for the utility to cover its cash obligations over the next 30 to 60 days;
    2. Budgetary solvency – the capacity for the utility to cover budget appropriations within the current budget cycle;
    3. Structural (long term) solvency – the relationship of assets to long term liabilities over time; and
    4. Service level solvency – the capacity for the utility to maintain a target Level of Service over multiple budget cycles.
  - C. Fiscal Capacity

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Reporting of Capital Assets

- One of the main goals of the new reporting model is to provide information about the "full cost" of providing government services.
- Cost of services must include the consumption of capital resources used to provide those services.
- Two techniques for estimating those "consumption of capital" costs are available:
  - Depreciation
  - "Modified" (preservation) method

Why Two Methods of Valuation?

Finite-lived versus Indefinite-lived Capital Assets:

"Consumable" Assets:

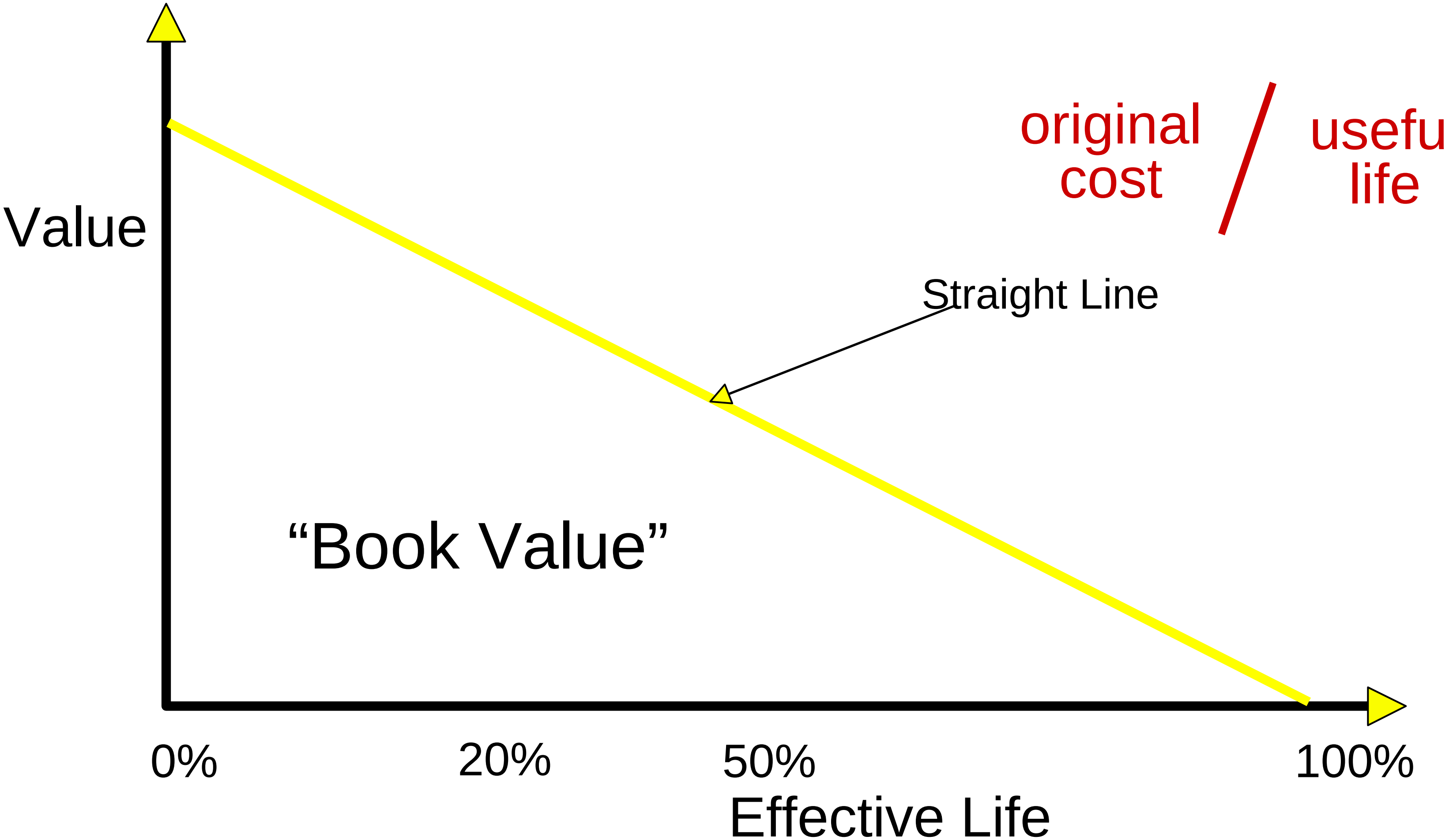
- **Vehicles**
- **Equipment**
- **Metal Building**
- **Signs**
- **Furniture and Fixtures**

"Preservable" Assets:

- **Roads**
- **Bridges**
- **Stormwater Systems**
- **Water/Sewer**
  - **Collection systems**
  - **Distribution systems**
  - **Treatment Plants**

Basic Depreciation Method

- Straight line depreciation
  - easy to apply but rarely a true reflection of decay

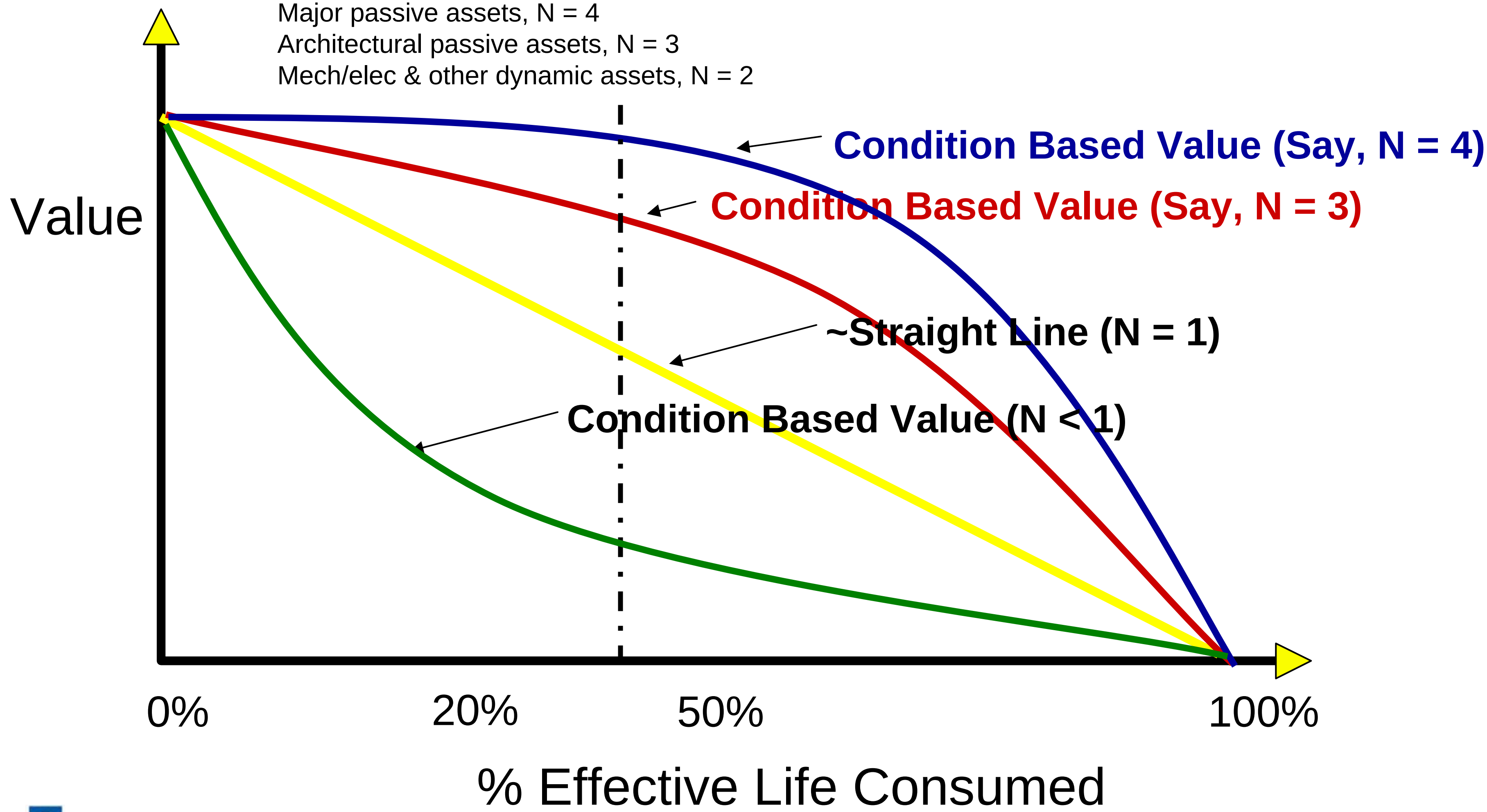


Condition-Based Depreciation

CB Depreciated Cost = (Life to date/estimated useful life)^{N} * Original Cost

Renewal cost = (% Effective Life Consumed)^{N} * Replacement Cost

Major passive assets, N = 4
Architectural passive assets, N = 3
Mech/elec & other dynamic assets, N = 2



Introducing “Economic Life”

Economic life:

- The period from the acquisition of the asset to the time when the asset, while physically able to provide a service, ceases to be the lowest cost alternative to satisfy a particular need.
- The economic life is, at the maximum, equal to the physical life, but obsolescence will ensure that the economic life is often less than the physical life.

Alternative GAAP Valuation Method

- “Modified (Preservation) Method
  - Based on *historic* cost
  - Historic cost is not reduced if the condition of the asset is preserved
  - Requires setting a measurable condition or performance standard (level of service)
  - Requires condition to be measured and disclosed at least every three years

Preserved historic cost
(renewal costs are expensed each year)

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Two Accounting Views

- <u>Financial accounting</u>
  - GAAP driven
  - Financial statement report ... al
  - "fairly present the re ... ations on financial condition" test
  - "Audit trail" paradigm
- <u>Managerial accounting</u>
  - Not GAAP driven, rather,"business ca ... *decision focused*
  - Management analysis repor ... nal
  - "Cost" focused

Original Cost

Replacement Cost

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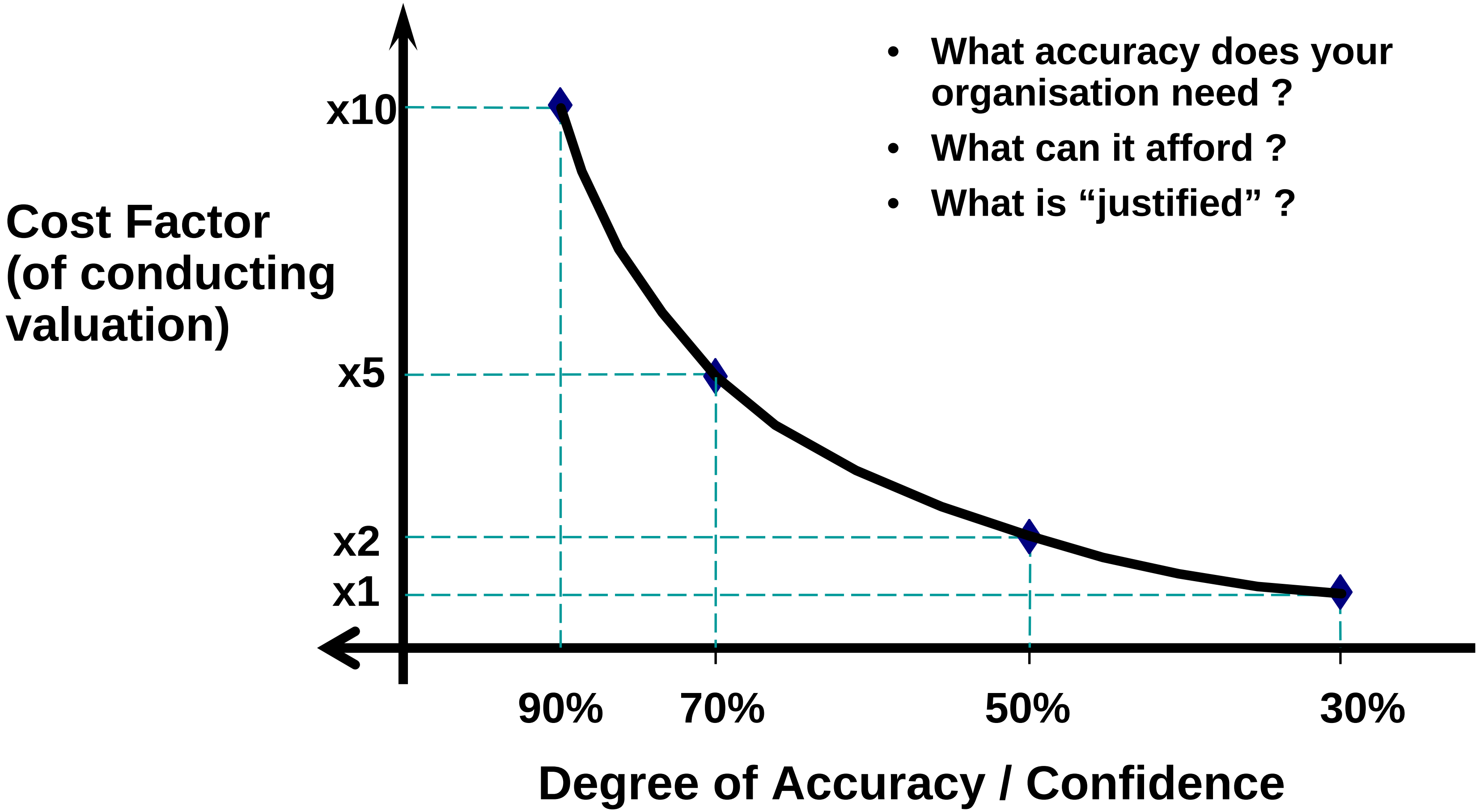
Determining Replacement Cost

- Level 1
  - Original cost x General Cost Index (eg, CPI)
- Level 2
  - Original cost x Sector-based Cost Indices (eg, ENR, Means CCI)
  - “Greenfields to Brownfields” conversion costs
- Level 3
  - “Modern Equivalent Engineered Replacement Asset” (MEERA)
  - Detailed site-based cost analysis

Cost Versus Accuracy

- What accuracy does your organisation need ?
- What can it afford ?
- What is “justified” ?



Management Engineering Environment GHD Clients People Performance

Which Valuation Technique?

Financial Accounting

- Used for GASB reporting purposes
- Choice of:
  - Historic depreciation
  - Modified or "preservation" approach

Managerial Accounting

- For renewal and replacement analysis
- For long-term funding strategies including rate setting
- Choice of:
  - Condition-based renewal
  - Depreciated replacement

Exercise Number 1c

- Now, let's add some Life-Cycle costs and replacement cost info;
  - Historic operating costs and trend
  - Historic maintenance costs and trend (and maintenance characterization from Tab B – is this consistent with our Expected Life Adjustment Factors?)
  - Replacement cost

Exercise Number 1c

- What is the current “book value” of the pump station?
- How much “depreciation reserve” has been accumulated so far? Do you think this is cash available to Tom to reinvest?
- How much depreciation expense is expected be “accumulated” over the life of the existing assets? Will this be enough to replace the assets?

AGENDA

<u>*Day 1*</u>

- *Welcome, Introductions & Housekeeping Details*
- *"Storyline" Introduction, Background And Context*
- *Overview Of Fundamental Concepts & Core Practices*
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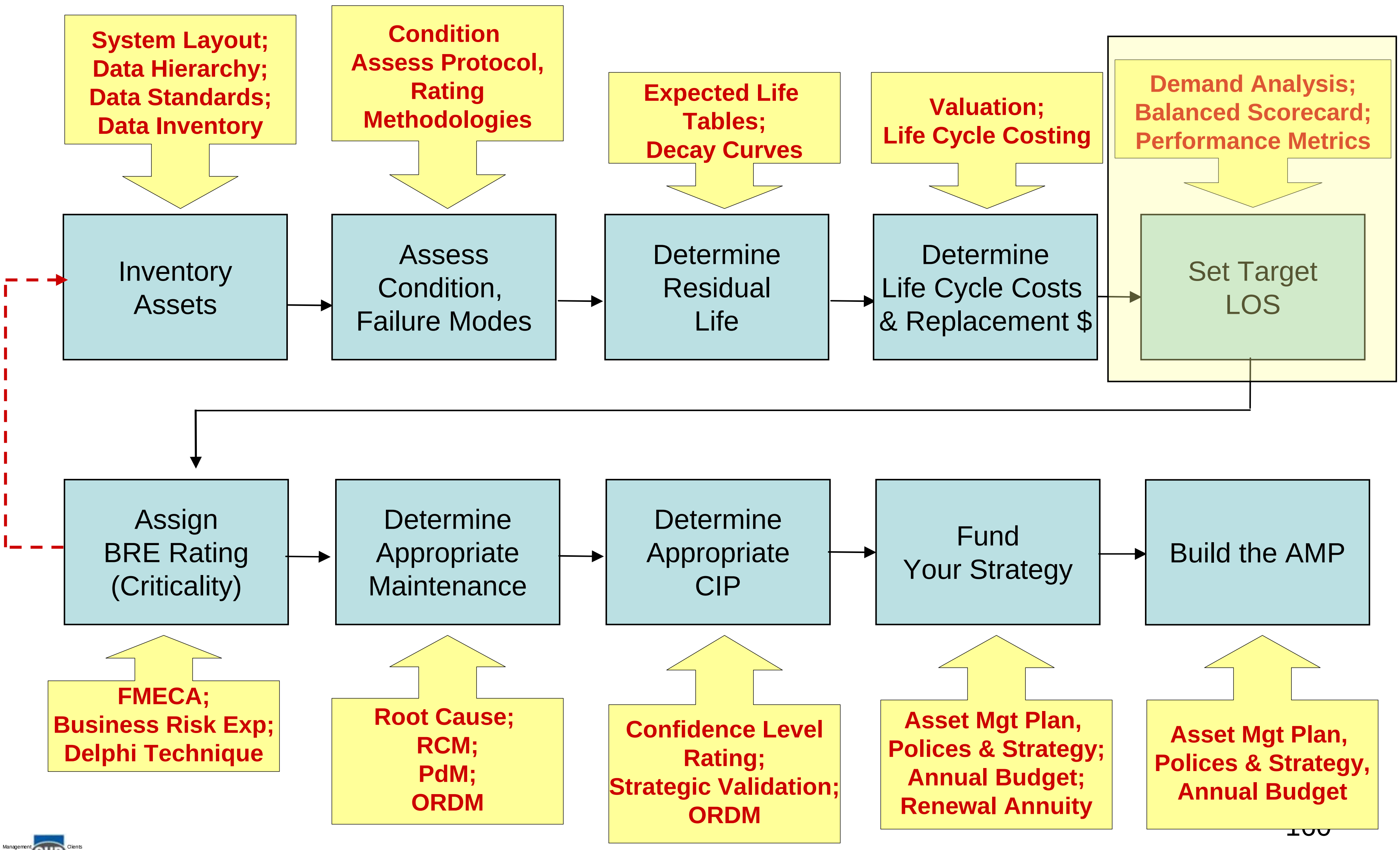
- *Core Question 1: What Is The Current State Of My Assets?*
- *Core Question 2: What Is My Required "Sustainable" Level Of Service?*
- *Core Question 3: Which Assets Are Critical To Sustained Performance?*
- *Review of Key Slides; Discussion /Q & A*

Management Engineering Environment GHD Clients People Performance

Question 2: LOS?

Core Questions
1. What is the current state of my assets? • What do I own? • Where is it? • What condition is it in? • What is its remaining useful life? • What is its economic value?
2. What is my required sustained Level Of Service? • What is the demand for my services by my stakeholders? • What do regulators require? • What is my actual performance?
3. Given my system, which assets are critical to sustained performance? • How does it fail? How can it fail? • What is the likelihood of failure? • What does it cost to repair? • What are the consequences of failure?
4. What are my best "minimum life-cycle-cost" CIP and O&M strategies? • What alternative management options exist? • Which are most feasible for my organization?
5. Given the above, what is my best long-term funding strategy?

The 10-Step Asset Management Plan Process



“Levels of Service”

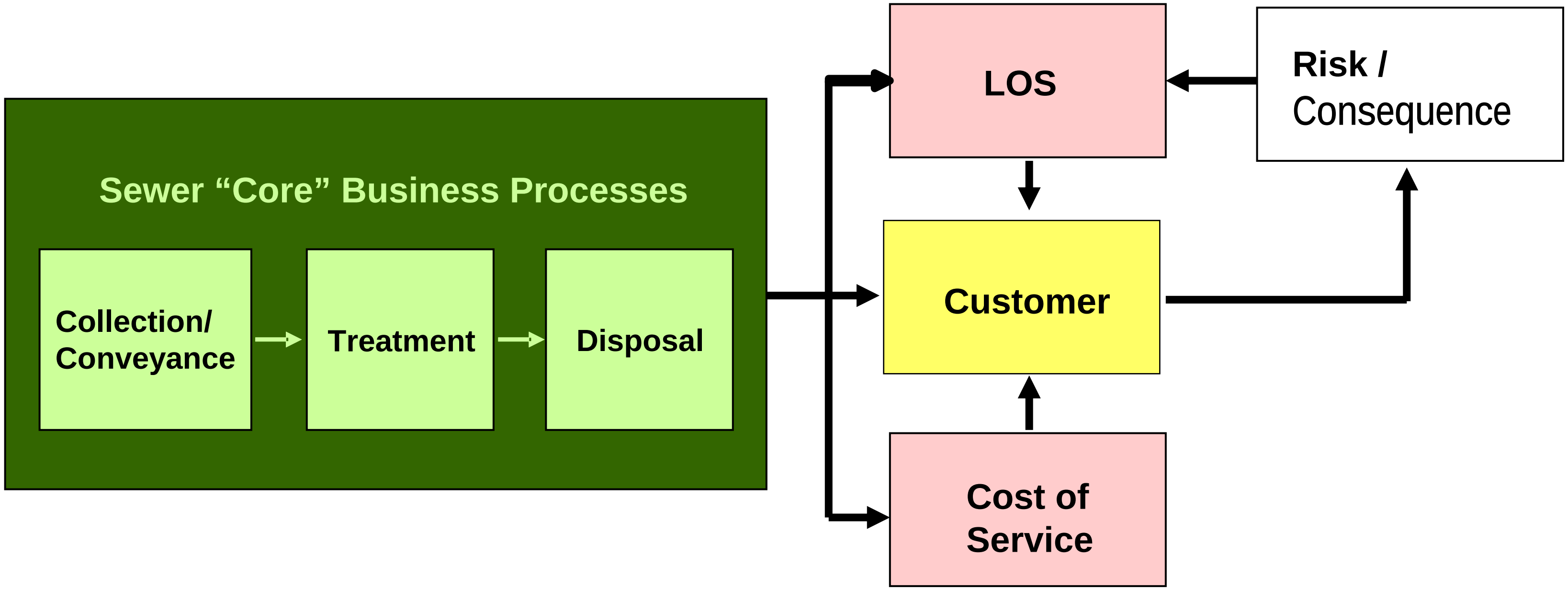
- Good output-oriented management is driven by a defined standard or level of service.
- Where that LOS is:
  - Driven by customers/user demand
  - As determined by the appropriate legislative body in a political arena
  - Tied at the “strategic” organizational level to the “tactical” asset level
- LOS can be defined as:
  - Characteristics or attributes of a service that describe its required level of performance;
  - These characteristics typically describe “how much”, “of what nature” and “how frequently” about the service.

Why LOS?

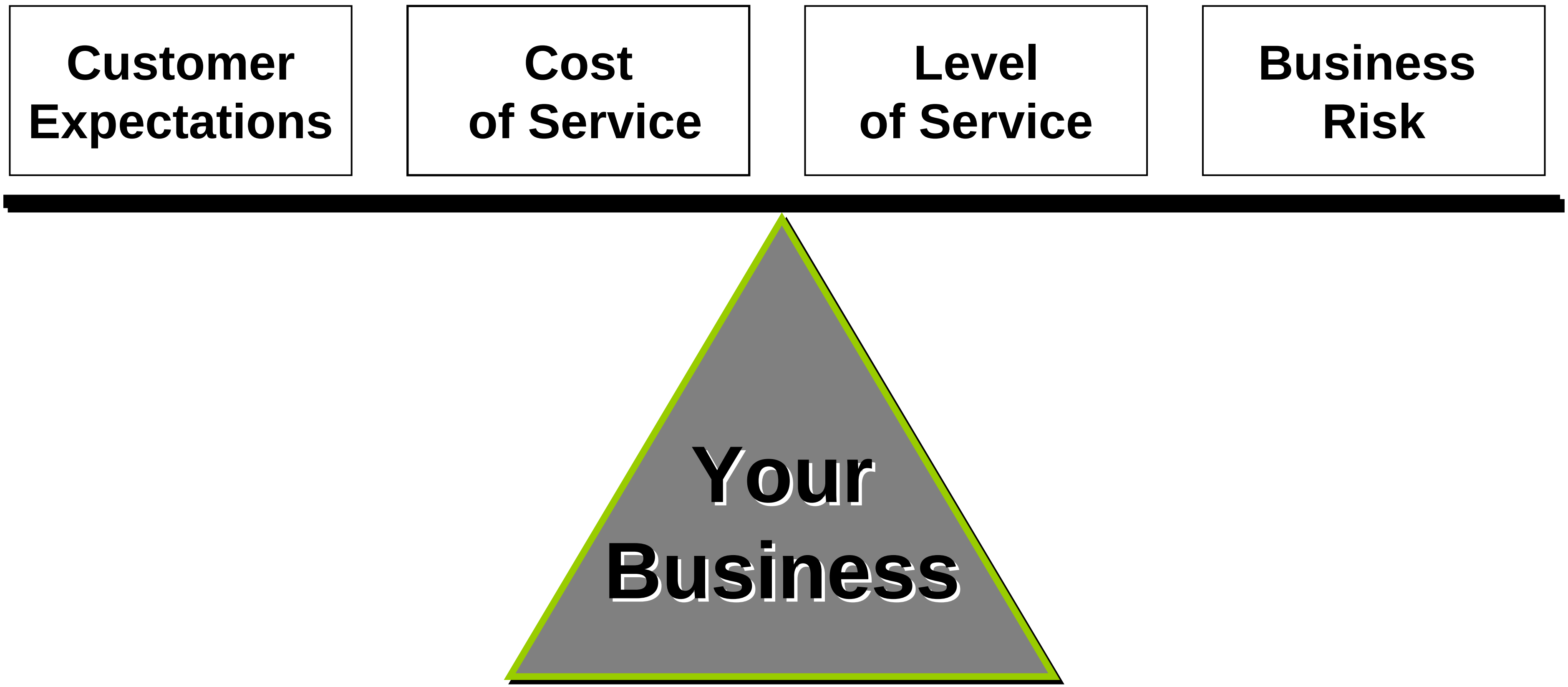
It helps us…

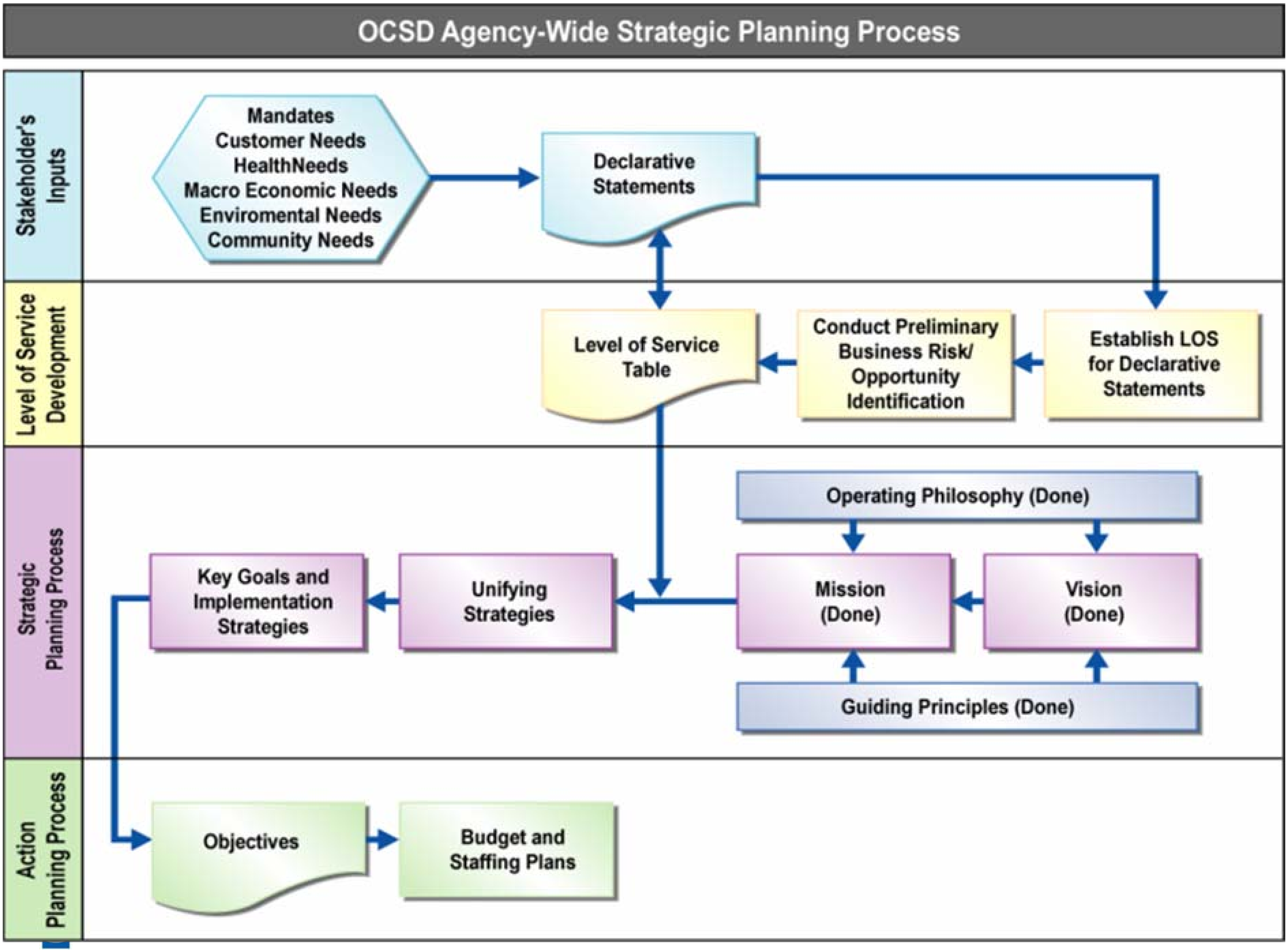
- Concentrate (focus) efforts & resources
  - On agreed on service levels
  - Less “service level defined by notion”
- Communicate service expectations and choices
  - Increased service = increased costs
  - Discussion of trade-offs & risks
- Negotiate
  - service levels
  - Costs & budgets
  - Rate impacts
  - Reinvestments for Renewal and Replacement
  - Level of Risk

LOS's Strategic Position



The Management Model

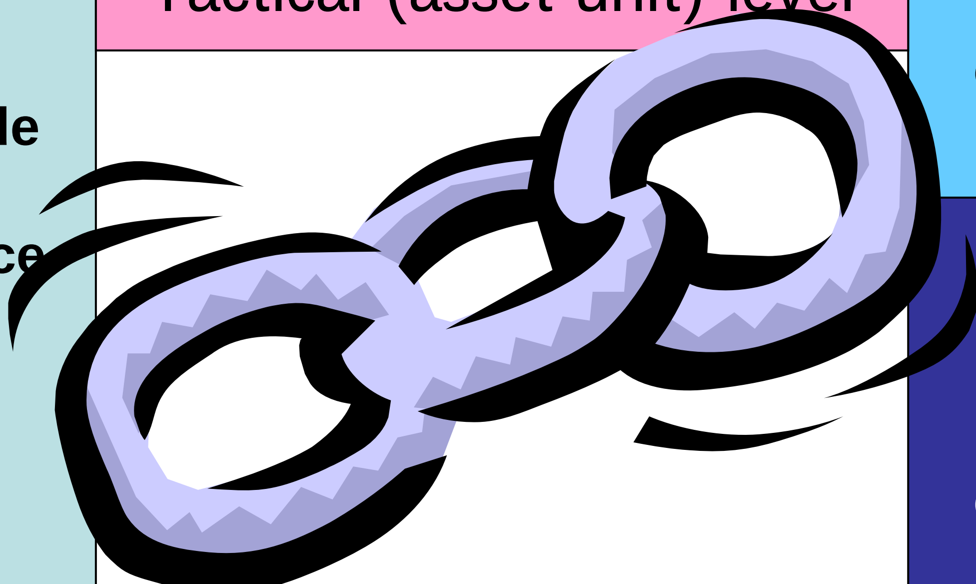



OCSD Agency-Wide Strategic Planning Process
Stakeholder's Inputs
Level of Service Development
Strategic Planning Process
Action Planning Process
Mandates
Customer Needs
HealthNeeds
Macro Economic Needs
Enviromental Needs
Community Needs
Declarative Statements
Level of Service Table
Conduct Preliminary Business Risk/ Opportunity Identification
Establish LOS for Declarative Statements
Operating Philosophy (Done)
Key Goals and Implementation Strategies
Unifying Strategies
Mission (Done)
Vision (Done)
Guiding Principles (Done)
Objectives
Budget and Staffing Plans

Alignment of O&M and Capital Tactics with Organizational Strategies

Agency-wide Asset Performance Targets

LOS Performance Targets:
Strategic (customer) level
Tactical (asset unit) level



O&M

Plan → Sched → Execute → Control Eval → Plan

Capital

Plan → Sched → Execute → Control Eval → Plan

Performance-based Asset Management

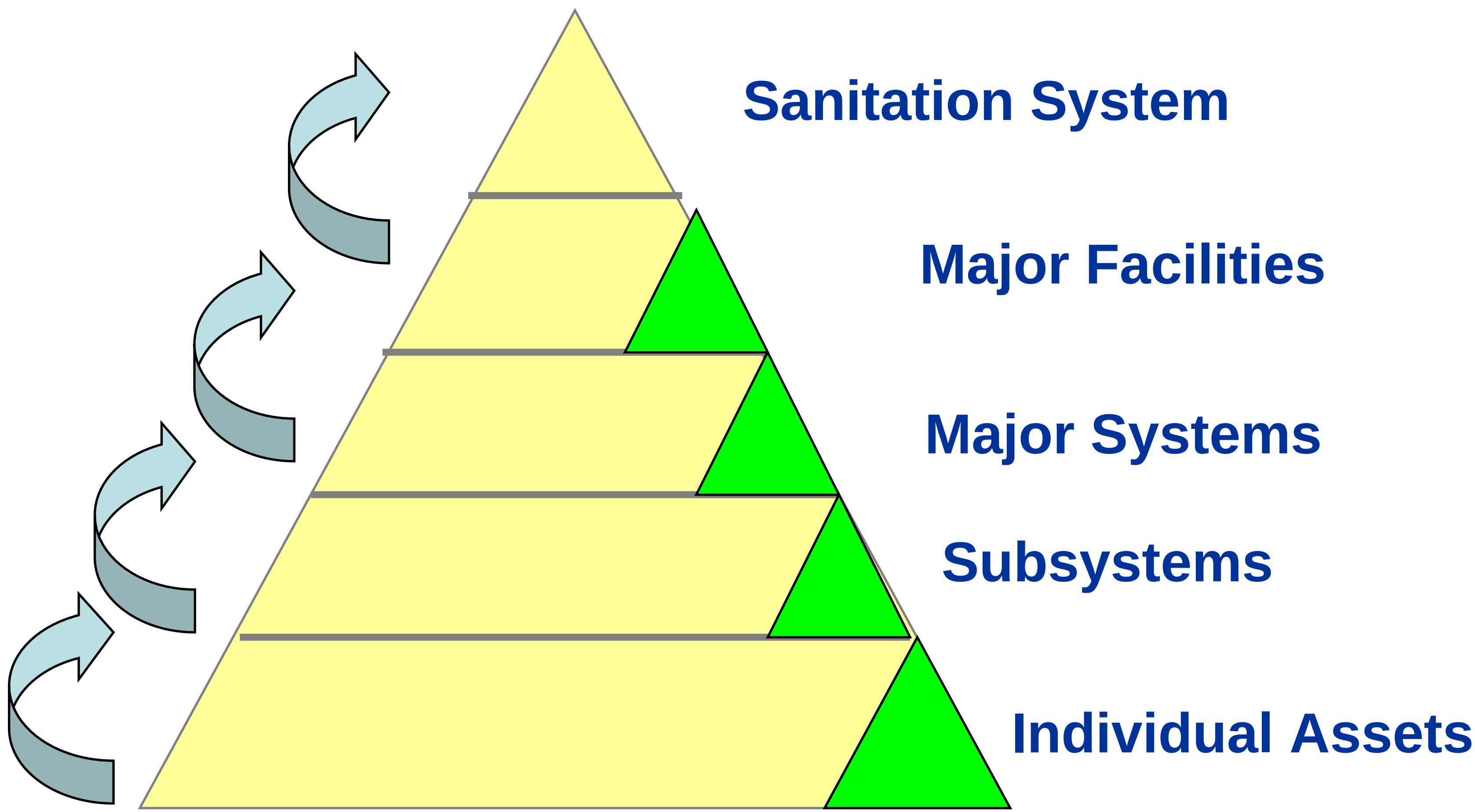
Performance = Adequacy Reliability Efficiency

Service = customer *perception* of performance

Nature of LOS

- LOS occurs at multiple levels
    - Agency-wide
    - Groups or systems of assets (collection system, treatment plants)
    - Assets (individual pump stations, digesters, clarifiers)
    - Key asset components (pumps, motors, vfd's)
- LOS targets are established to "roll up" to meet higher level targets
- There are internal and external LOS targets
    - External LOS targets are typically strategic or "KPI" outcomes:
        - Driven by customers/user demand
        - Confirmed or determined by the appropriate legislative body in a political arena
    - Internal LOS targets are typically tactical and geared toward focusing activities

The “Roll-up” of LOS



The LOS of each layer can only be met by delivering related LOS at underlying levels.

ENVIRONMENTAL

Key Performance Indicators
1. OCSD will comply with e
a. Compliance with all Oc
b. Concentration of Emerg Plant No. 1 Secondary E
c. Effluent total coliform ba
d. Source Control permite percent
2. OCSD will manage flows
a. Frequency of use of em
b. Sanitary sewer spills pe
c. Contain sanitary sewer
3. OCSD's effluent will be re
a. Treated effluent reclaim
4. OCSD will implement a su program.
a. National Biosolids Progr Management System
b. Percent of biosolids ber Class "B" Class "A/EQ"
5. OCSD will improve the re
a. Dry weather urban runo
b. Rainfall induced inflow a
c. Stormwater manageme treated on-site
d. Per capital wastewater
6. OCSD will protect the air
a. Odor complaints: Recla Treatment Pl Collection Sy
b. Air emissions health risk Community, Employees
c. Air mass emissions perr

SOCIAL

Key Performance Indicators	2005 Target Level of Service
1. OCSD will be a good neighbor and will be responsive to its customers.	
a. Off site Biosolids nuisance complaints	0
b. Odor complaint response Treatment Plants within 1 hour Collection System within 1 working day	 100% 100%
c. Restore collection service to customer within 8 hours	100%
d. Respond to public complaints or inquiries regarding construction projects within 1 working day	>90%
e. Respond to collection system spills within 1 hour	100%
f. New connection permits processed within one working day	>90%
g. Dig Alert response within 48 hours	100%
2. OCSD will provide public access to OCSD information.	
a. Public Records Act requests within 10 working days	100%
b. Post Board/Committee Agenda Packages 72 hours prior to meeting	100%
c. Post studies and reports on OCSD website within 1 week of receive/file.	100%
3. OCSD will take care of its people.	
a. Training hours per employee	45
b. Employee Injury Incident Rate	<3.75

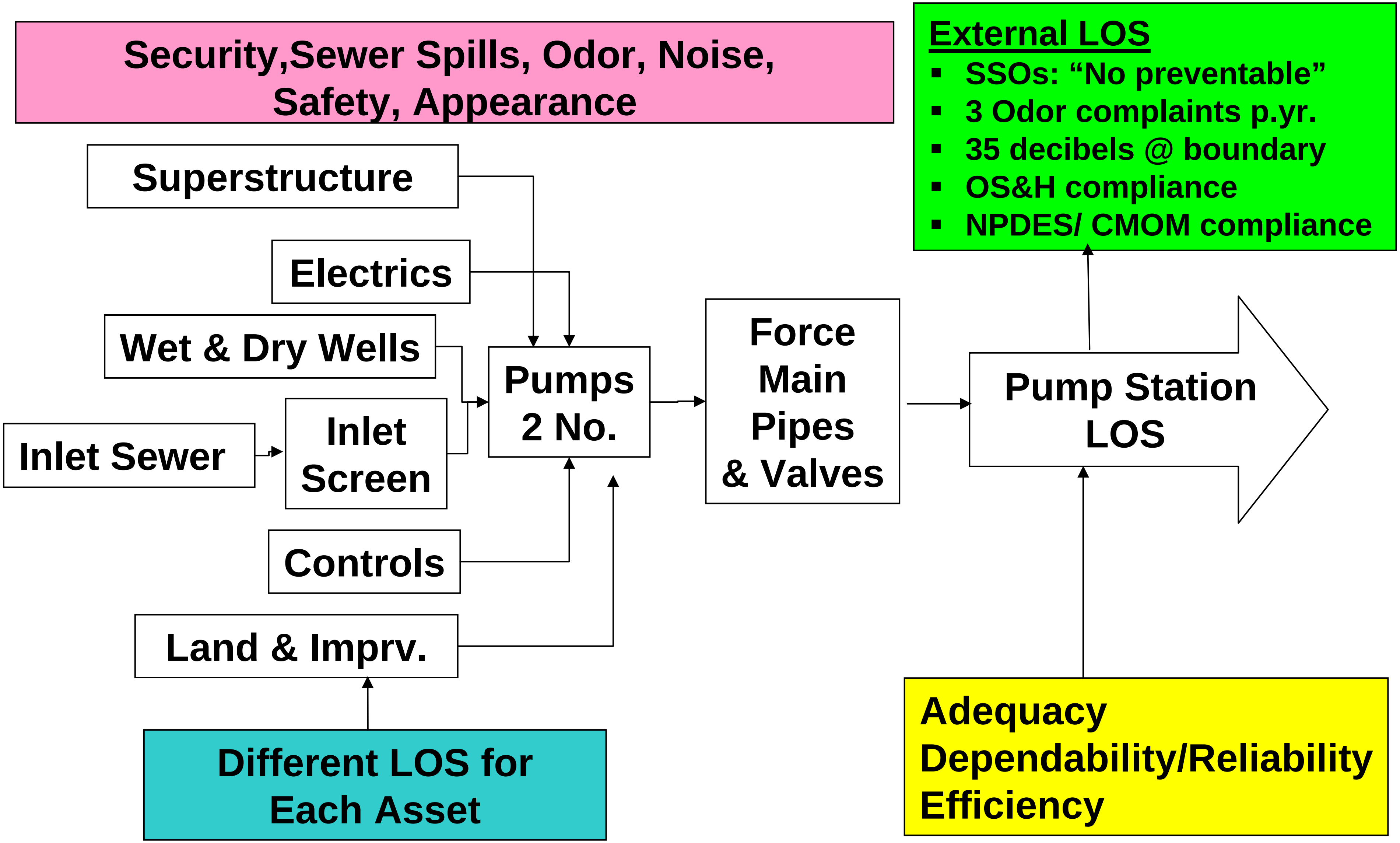
ECONOMIC

Key Performance Indicators	2005 Target Level of Service
1. OCSD will exercise sound financial management.	
a. New borrowing	Not more than annual Capital Improvement Program requirements
b. COP coverage ratio	Between 1.25 and 2.0
c. COP service Principal and Interest	< than O&M expenses
d. Annual SFR user fee increase	not more than 15%
e. Annual user fees	Sufficient to cover all O&M requirements
f. Annual increase in collection, treatment, and disposal costs per million gallons	< 10%
g. Annual variance from adopted reserve policy	<5%

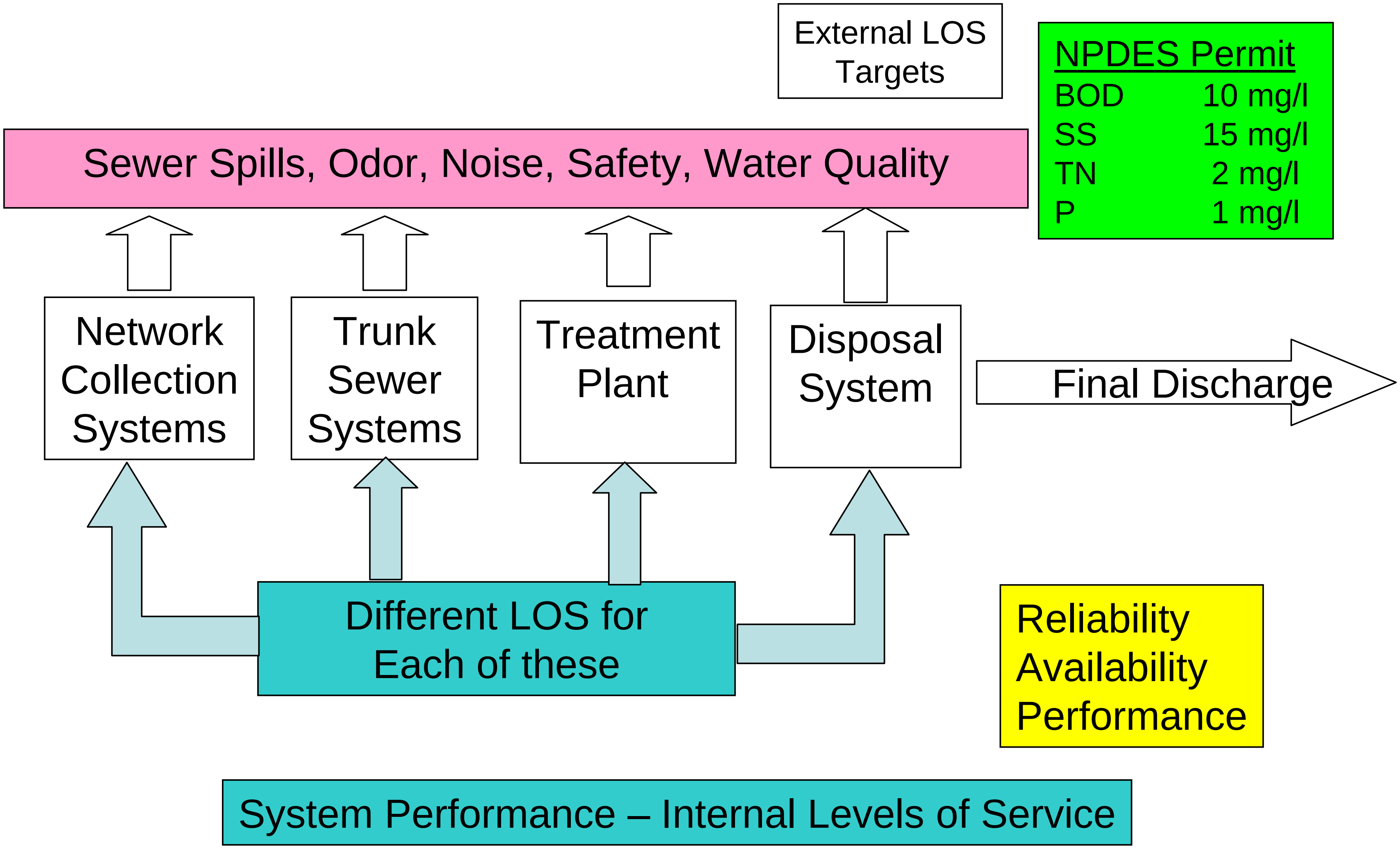
Example: LOS Statement

Management Engineering Environment GHD Clients People Performance

Pump Station LOS Requirements



System Performance Requirements



The Four Major Failure Modes

Mode	Definition	Tactical Aspects	Management Strategy
1. Capacity	Volume of demand exceeds design capacity	Growth, system expansion	Redesign
2. LOS	Functional requirements exceed design capability	Codes/permits: NPDES, CSOs, SSOs, OSHA, noise, odor, life safety; service, etc	Redesign
3. Mortality	Consumption of asset reduces performance below an acceptable minimum level	Physical deterioration due to age, usage (including operator error), acts of nature	O&M, Renewal
4. Efficiency	Performs ok, but cost of operation exceeds that of feasible alternatives	"Pay-back" period	Replace

Exercise 2 (LOS) 2

- *Help Tom develop LOS targets for his “problem” pump station*
- *Translate these to “Performance” and “Reliability” scores (Tab D)*

Management Engineering Environment GHD Clients People Performance

Pump Station LOS

Performance	Measure	Current	Target
Odor	*Complaints/yr*	***0.5***	***1***
Spills	*#/yr*	***2***	***0***
	Gals/spill	***56,000***	***2,000***
Pumping	*% influent*	***99.68%***	***100%***
Reliability			
Scada	*Outages/yr*	***7***	***2***
	Duration, hrs	***72+***	***8***
Power	*Outages/yr*	***1***	***1***
	Duration, hrs	***7***	***2.5***

Pump Station LOS

Reliability	**Measure**	**Current**	**Target**
Pumps	*% reserve capacity, Peak Q*	*30%*	***30%***
	% redundancy @ peak Q	*0%*	***50%***
Power	*2^{nd} source, hrs*	*7*	***2.5***
Regulatory			
Spill reporting	*verbal, hrs*	*N/A*	***24***
	Report, days	*21*	***10***
	Impact Notice, hrs	*N/A*	***8***
	Response plan trng, hrs/yr	*0*	***8***

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- *Discussion /Q & A*

Question 3: "Critical" Assets?

Core Questions
1. What is the current state of my assets? • What do I own? • Where is it? • What condition is it in? • What is its remaining useful life? • What is its economic value?
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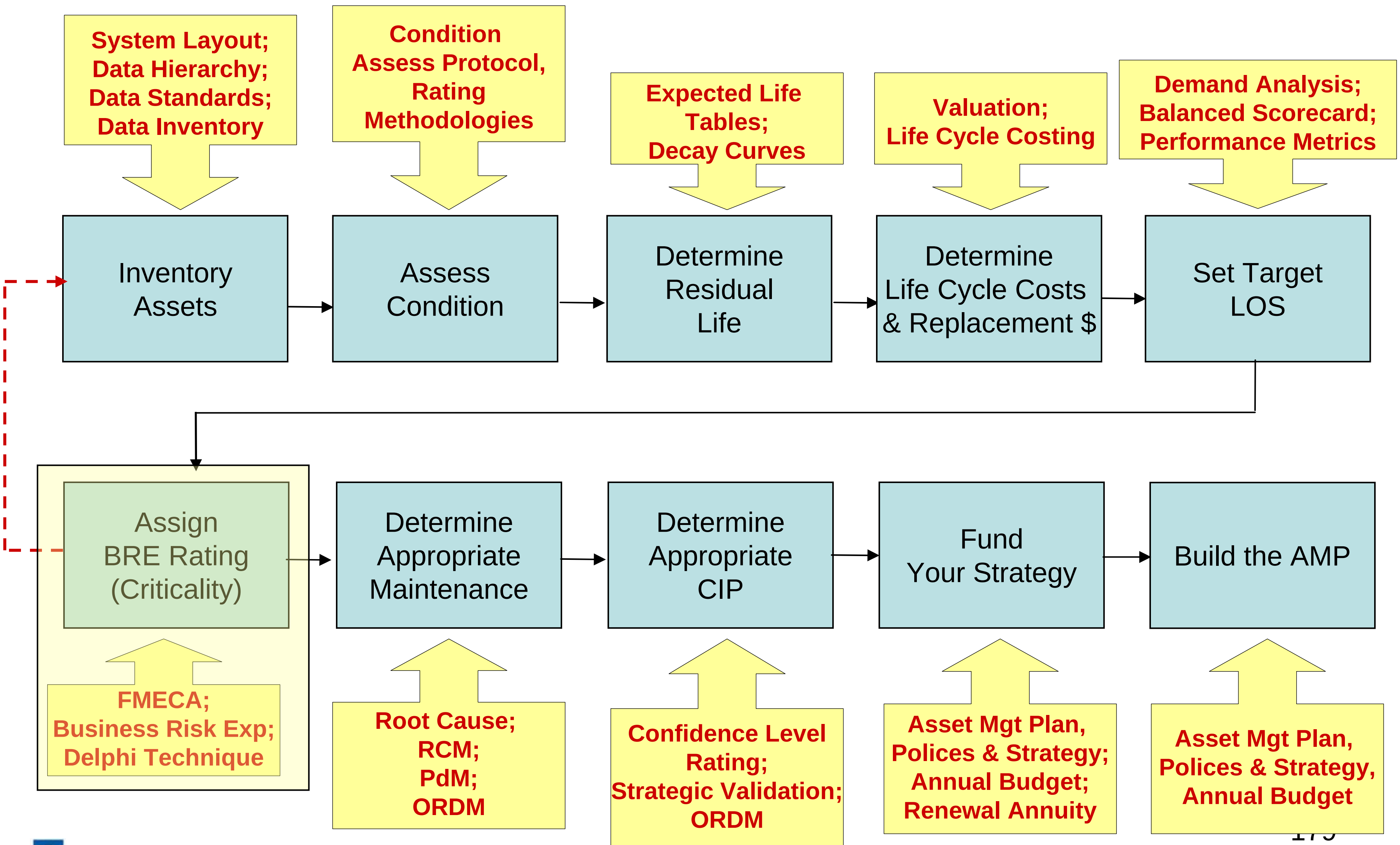
The 10-Step Asset Management Plan Process



“Risk” is The Heart Of AM

RISK:
Potential for Failure
vs
Consequence of Failure

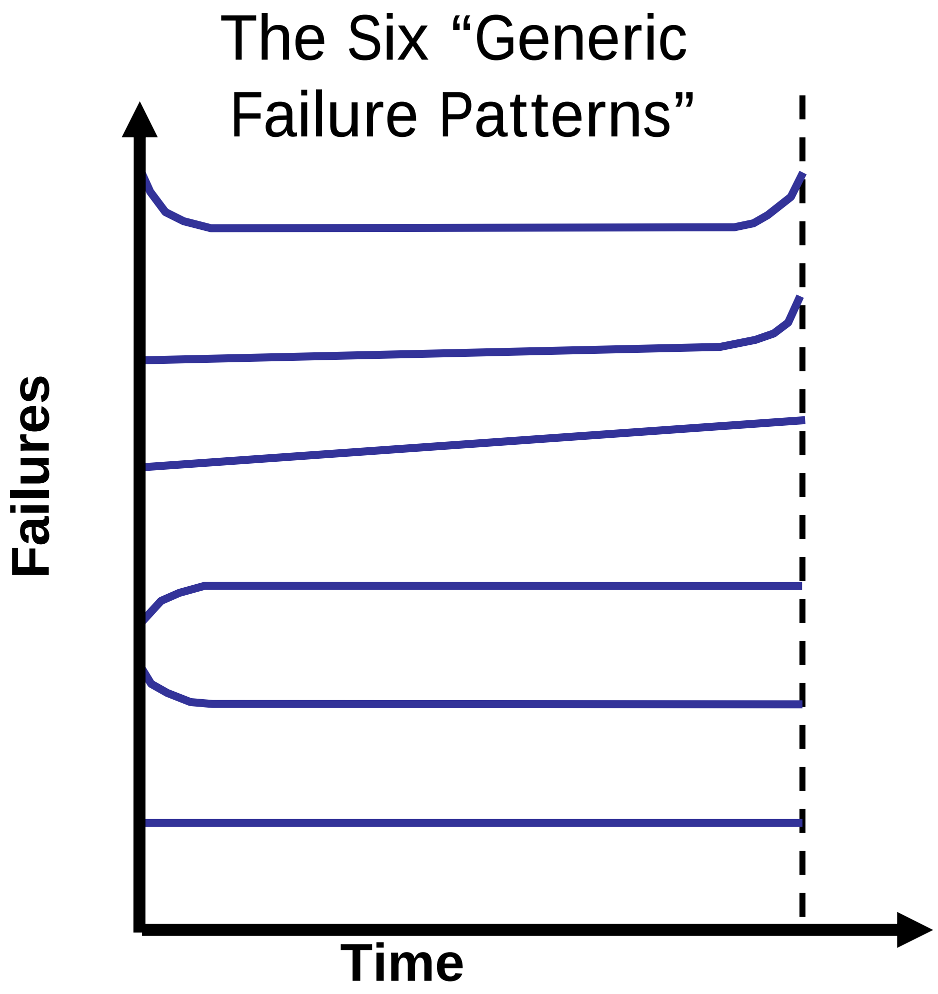
Definition of "Risk"

- "Risk" in "AM speak" is the *consequence of failure weighted by the probability of failure;*
- It is often used as a measure of "Criticality".

Variables:

1. The probability or likelihood of the event (PoF)
2. The consequence or impact of the event (CoF)

All Assets Have a "Probability of Failure"

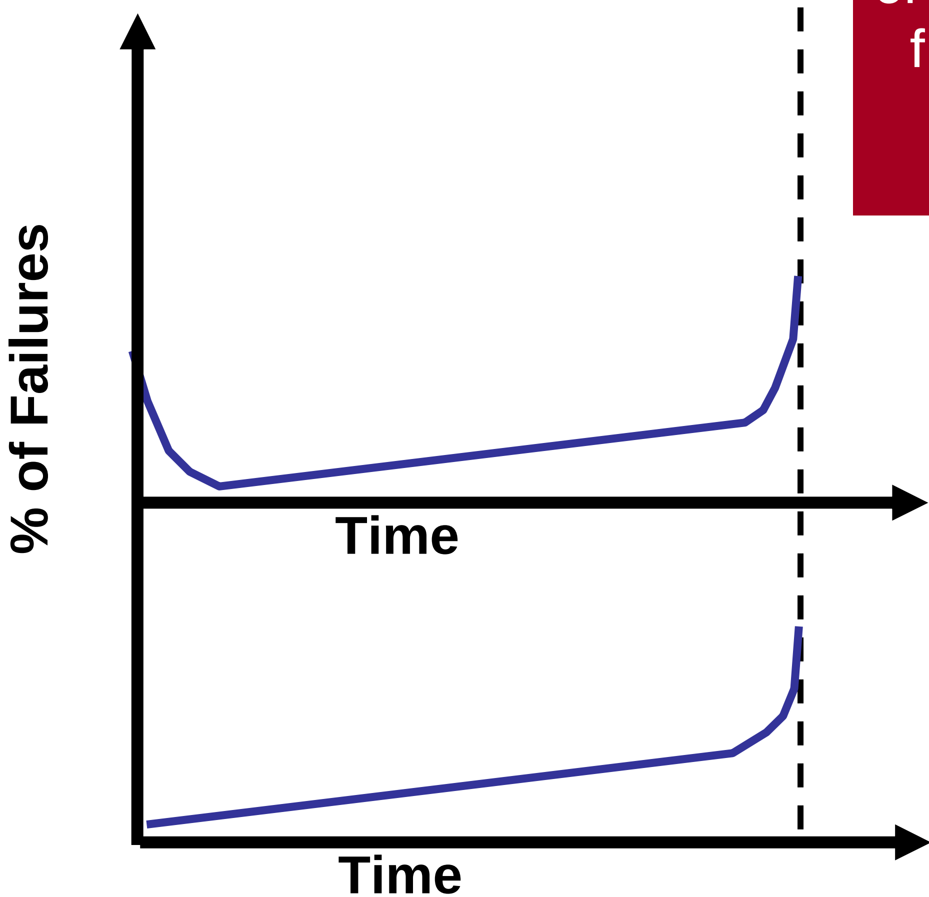


<u>Two Key Questions:</u>

1. Is the failure reasonably *predictable*?
2. Is it *preventable* in cost-effective terms?

The Two Most Common “Reliability” Failures

“The Two Key Failure Patterns”



Reliability Analysis

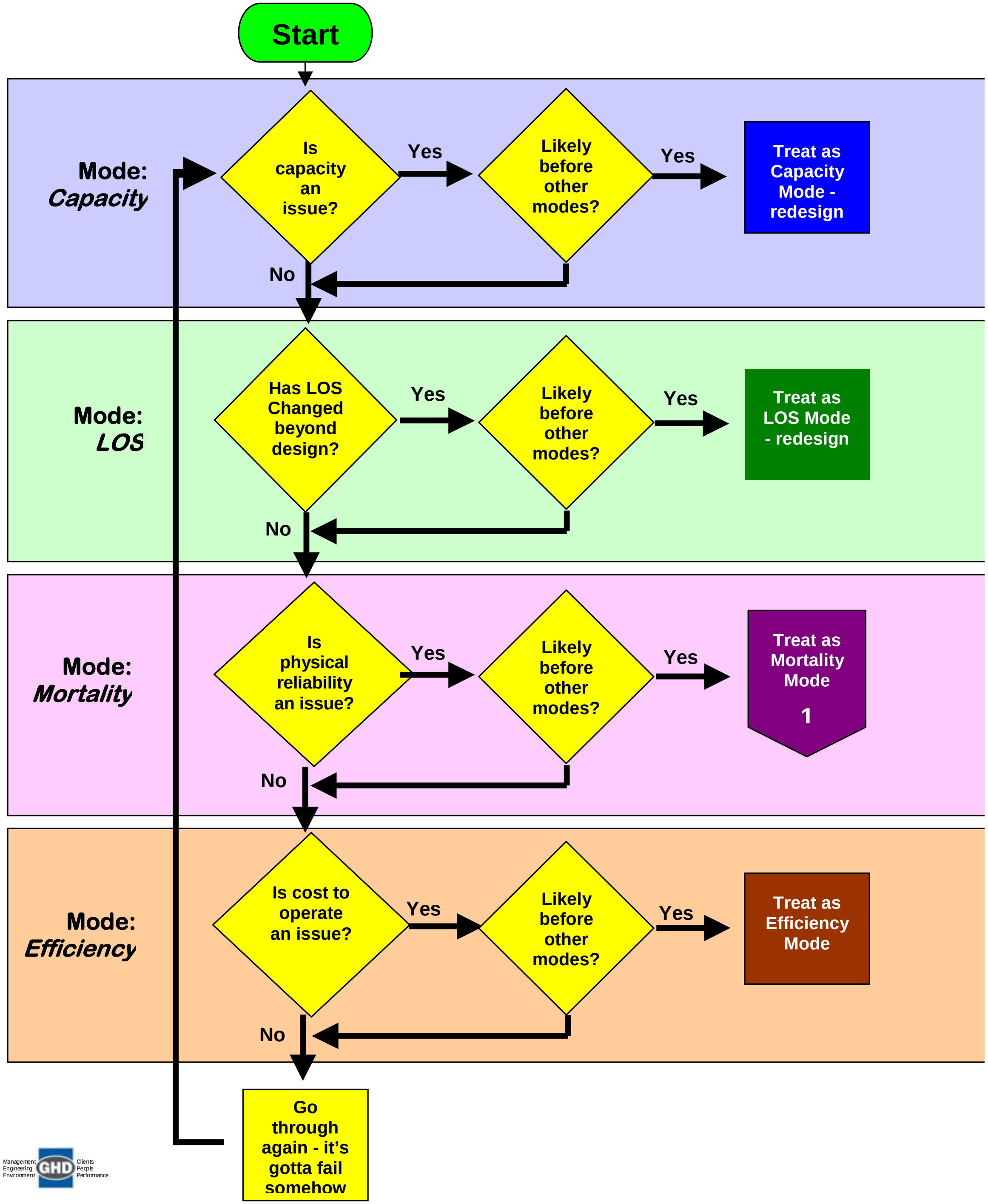
“The probability that a component or system will perform its specified function for the specified period under specified operating conditions”

1. The Bathtub Curves
Typically applicable for mechanical and electrical assets

2. Time /Age Based Curves
Typically applicable for civil passive assets

The Four Major Failure Modes

Mode	Definition	Tactical Aspects	Strategic Management Strategy
1. Capacity	Volume of demand exceeds design capacity	Growth, system expansion	Redesign
2. LOS	Functional requirements exceed design capability	Codes: NPDES, CSOs, SSOs, OSHA, noise, odor, life safety; Service, etc	Redesign
3. Mortality	Consumption of asset reduces performance below an acceptable minimum level	Physical deterioration due to age, usage (including operator error), nature	O&M, Renewal
4. Efficiency	Performs ok, but cost of operation exceeds that of alternatives	"Pay-back" period	Replace



The "Primary Failure Mode" Gives Insight Into Setting the Probability of Failure

Failure Analysis

- Performance Parameters
- What To Monitor

- Failure Cause
- Failure Behaviour
- Failure Mode

- Failure End State
- Failure Consequences

Function

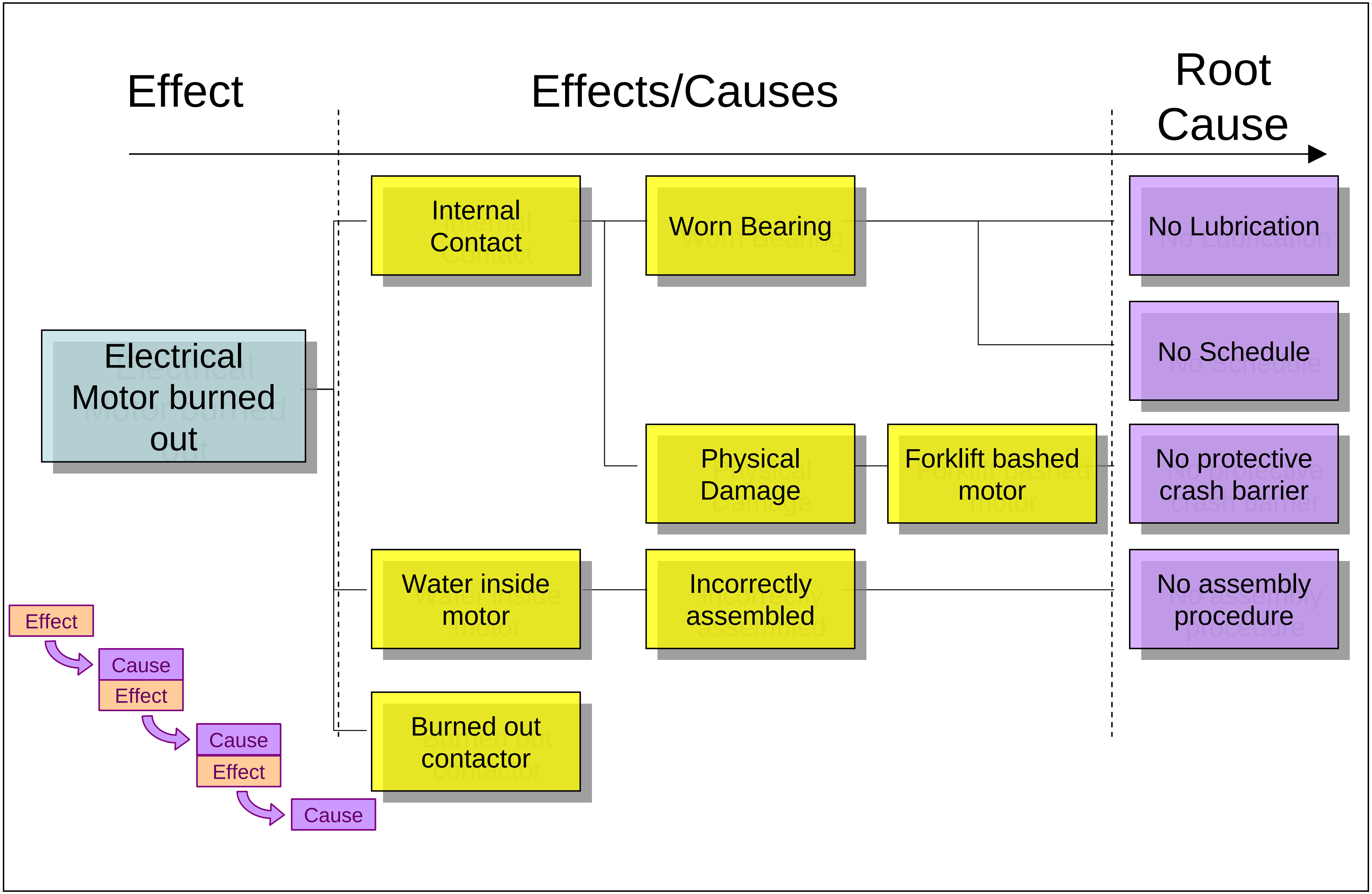
(It works)

Functional Failure

(It doesn't work)

Function	**Functional Failure**	**Failure Cause**	**Failure Mode**	**Failure Behaviour**	**Failure Consequences**
Defined by performance standards	End state or potential end state; Evidence - what you see	Contributing causes and Root Cause; Reason why failure occurred	Mechanism of failure	Evident; Hidden; Random; P-F Interval	Cost, Safety, Environmental

Cause and Effect Diagrams



Probability of Failure (PoF)

- The PoF is directly related to the Failure Mode
- We cannot absolutely determine the PoF.
- Sometimes we have good data, sometimes we do not.
- We can estimate a range of failure - how early (pessimistic) and how late (optimistic).

The “FMECA” Structure

(“Failure Mode, Effects and Criticality Analysis”)

MAJOR FAILURE MODE/S IDENTIFIED

	CAPACITY DEMAND AVAILABILITY QUANTITY		LEVEL OF SERVICE REGULATORY POLICY	MORTALITY END OF PHYSICAL LIFE	COST PERFORMS OKAY BUT COSTS TOO MUCH
MODES	DEMAND EXCEEDS CAPACITY (SUPPLY)	DEMAND INADEQUATE UTILISATION OF ASSET IS POOR	ASSET IS UNRELIABLE AND INTERUPTS SERVICE DELIVERY TO UNACCEPTABLE LEVELS	ASSET STILL PERFORMING ADEQUATELY BUT FAILURE LIKELY	NON PERFORMING FINANCIALLY TECHNICALLY INEFFICIENT OR OBSOLETE.HAS POOR UTILISATION AND DERIVES LOW INCOME / INCOME
EFFECTS	FAILS TO MEET LEVEL OF SERVICE OR STANDARDS REQUIRED	HIGH COST OF SERVICE NON PERFORMING ASSET (FINANCIALLY)	HIGH NUMBER OF FAILURES IMPACTS ON CUSTOMERS. POOR LEVEL OF SERVICE	LOSS OF SERVICE IMPACT DEPENDENT ON DIRECT / INDIRECT CONSEQUENCES OF FAILURE	• HIGH MAINTENANCE AND / OR OPERATING COSTS • HIGH DEPRECIATION • FUTURE LIABILITIES ETC
TREATMENT	ASSET • AUGMENTATION • NEW ASSET • DEMAND • MANAGEMENT	ASSET • DISPOSAL • RATIONALISATION • INCREASE INCOME • CONTINUE SUBSIDY	• IMPROVE MAINTENANCE • REDESIGN • REHABILITATE • REPLACE / DISPOSE • LOWER SERVICE LEVEL	• COMPLETE RISK ASSESSMENT • COMPLETE ORDM • IDENTIFY OPTIMISED RENEWAL	• RATIONALISATION • DISPOSAL • OPTIMISED RENEWAL • LOWER LEVELS OF SERVICE RESPONSE TIMES etc

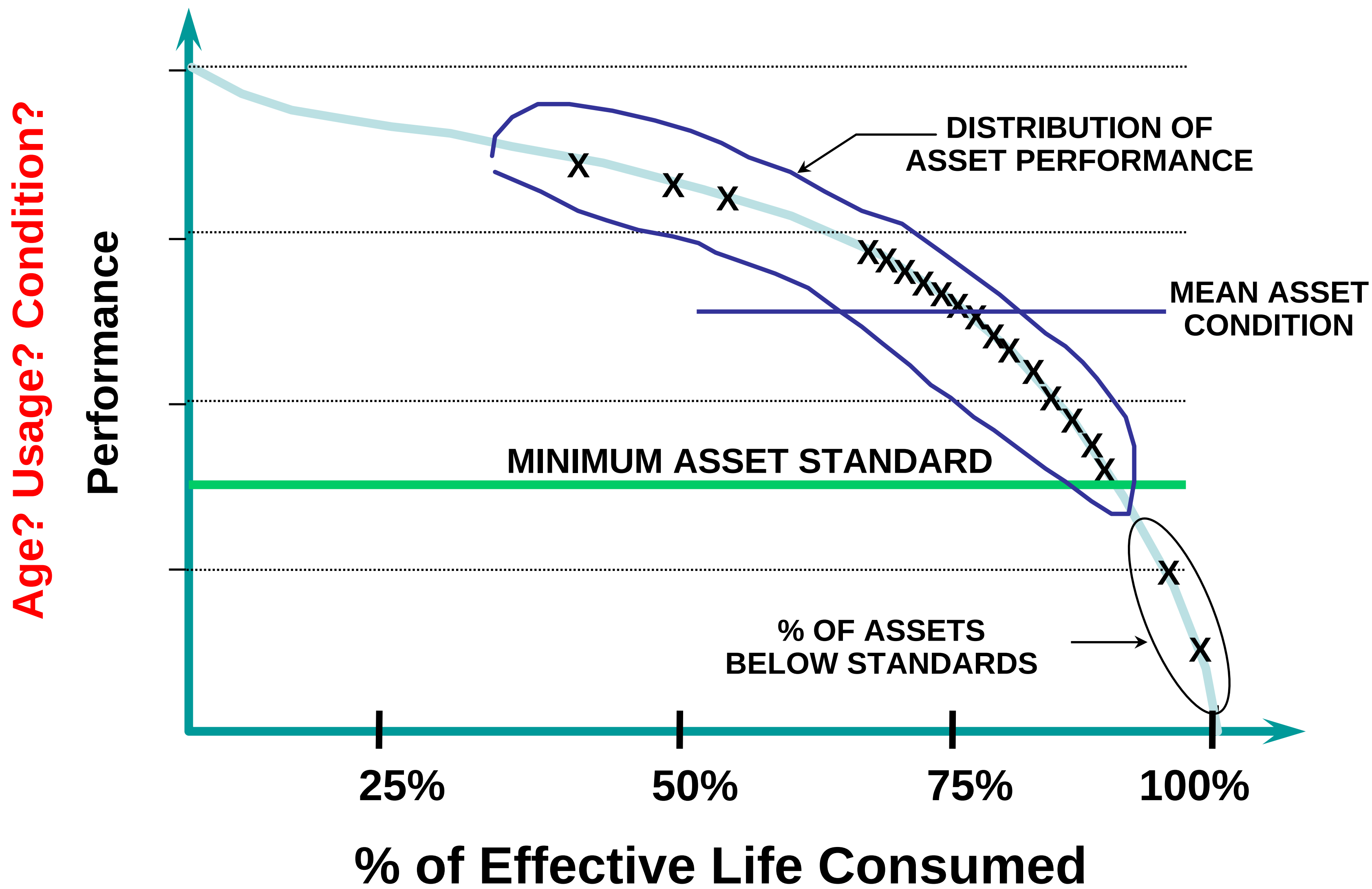
Modes → Effects → Treatment (Management) Alternatives

What are the Sources of PoF?

- CMMS – “Mean Time Between Failure” (MTBF)
- Vendor / industry information
- Other failure records (hard copies)
- Our “Brilliant Memories” (Staff)
- Our SCADA System (if we have one and it records this asset).

PoF – Probability of Failure

Finding a “Proxy” For “Performance”



Probability of Failure & Age of Asset

Probability of Failure	
% of Effective Life Consumed	**PoF Rating**
0%	**1**
10%	**2**
20%	**3**
30%	**4**
40%	**5**
50%	**6**
60%	**7**
70%	**8**
80%	**9**
90%	**10**

Probability of Failure & Condition

Conditon - Residual Life Facto	Condition/Residual Life									
Effective Lives	1	2	3	4	5	6	7	8	9	10
Civil	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Pressure Pipework	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Sewers	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Pumps	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Valves	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Motors	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Electrical	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Controls	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Building Assets	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Land	1	1	1	1	1	1	1	1	1	1

Condition Based Effective Liv	Condition/Residual Life									
Effective Lives	1	2	3	4	5	6	7	8	9	10
Civil	67.5	60	52.5	45	37.5	30	22.5	15	7.5	0
Pressure Pipework	54	48	42	36	30	24	18	12	6	0
Sewers	90	80	70	60	50	40	30	20	10	0
Pumps	36	32	28	24	20	16	12	8	4	0
Valves	27	24	21	18	15	12	9	6	3	0
Motors	31.5	28	24.5	21	17.5	14	10.5	7	3.5	0
Electrical	31.5	28	24.5	21	17.5	14	10.5	7	3.5	0
Controls	22.5	20	17.5	15	12.5	10	7.5	5	2.5	0
Building Assets	54	48	42	36	30	24	18	12	6	0
Land	300	300	300	300	300	300	300	300	300	300

PoF = 1.0 – “Condition/Residual Life Factor”

Direct Probability of Failure Table

Assessment (Likelihood of occurrence within one year)	Probability Weighting	Description
Almost Certain	100	Is expected to occur within a 1 year timeframe
Very High	75	Likely to occur within a 1 year timeframe
High	50	Estimated 50% chance of occurring in any year
Quite Likely	20	Is expected to occur within a 5 year timeframe Estimated 20% chance of occurring in any year
Moderate	10	Is expected to occur within a 10 year timeframe Estimated 10% chance of occurring in any year
Low	2	Is expected to occur within a 50 year timeframe
Very low	1	Is expected to occur within a 100 year timeframe

Note: calibrate to each class of assets!

Quantifying “Consequence of Failure”

Simple

Consequence of Failure			
CoF Rating	**Description**	**% Affected**	**Level**
1	Minor Component Failure	0-25%	Asset
2	Major Component Failure	25-50%	Asset
3	Major Asset	0-25%	Asset
4	Multiple Asset Failure	25-50%	Facility / Sub-System
5	Major Facilty Failure	50-100%	
6	Minor Sanitory System Failure	20-40%	
7	Medium	40-60%	
8	Intermediate	60-80%	
9	Significant	80-90%	
10	Total	90-100%	

Sophisticated

- **Direct Costs to the Local Government**
  - Repair and return to service costs
  - Service outage mitigation costs
  - Utility emergency response costs
  - Public safety costs
  - Admin & legal costs of damage settlements
  - (Lost product costs)
- **Direct Customer Costs**
  - Property damage costs (including restoration of business)
  - Service outage costs
  - Service outage mitigation and substitution costs
  - Access impairment and travel delay costs
  - Health damages
- **Community Costs**
  - Emotional strain/welfare
  - Environmental Pollution, erosion, sedimentation
  - Destruction of/damage to habitat
  - “Attractability” (tourist, economic)

Alternative View 1 of “Criticality”: Impact on Process

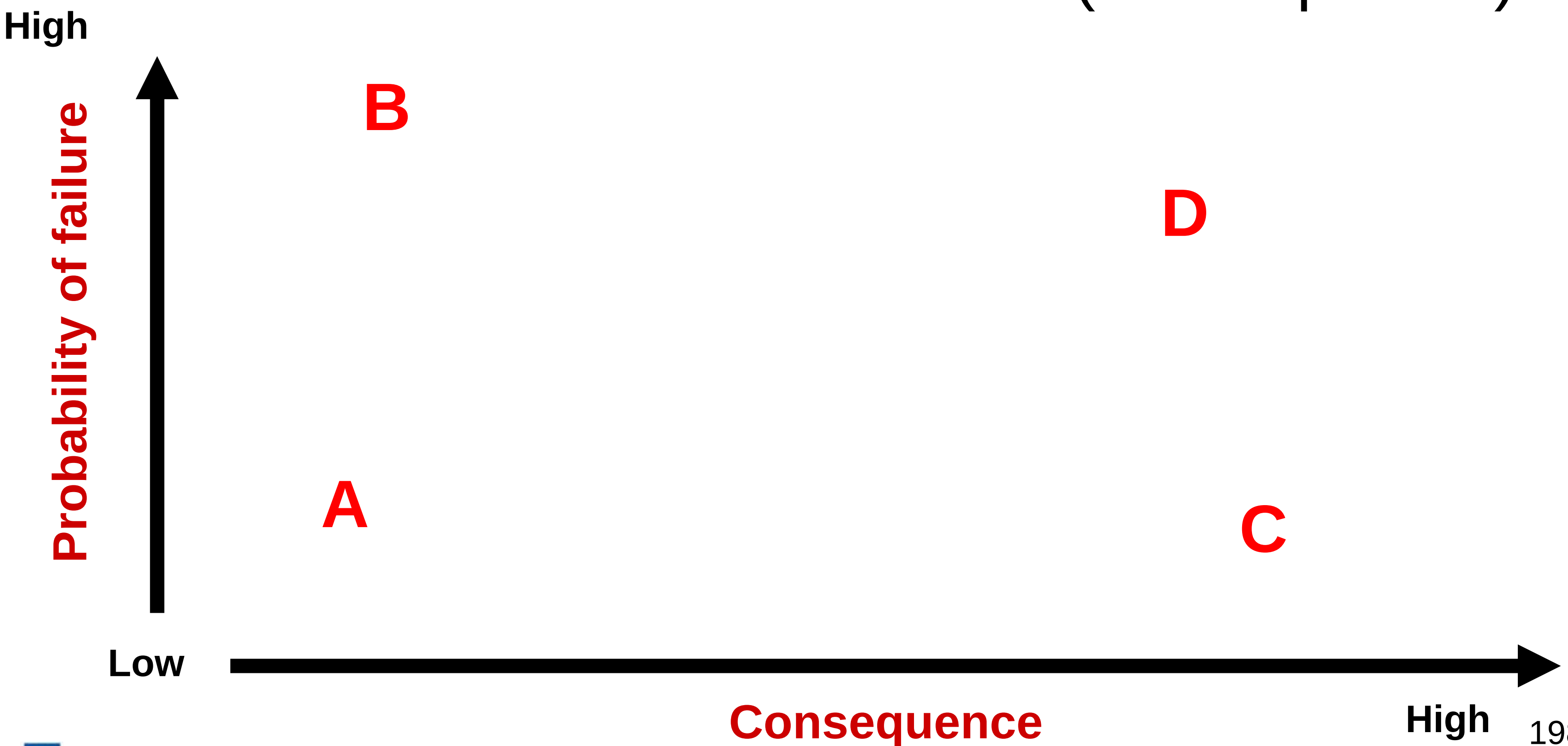
Code	Description
1	Mandated by law or corporate policy
2	Impacts multiple processes, runs continuous without an on-line spare
3	Impacts multiple processes, runs intermittently without an on-line spare, and/or causes lost production in less than 4 hours
4	Impacts a single process, runs intermittently without an on-line spare, and/or causes lost production between 4 - 24 hours
5	Impacts a single process, runs intermittently without an on-line spare, and/or causes lost production in less than 24 hours
6	Impacts multiple processes, runs continuous with an on-line spare, and causes no lost production
7	Impacts multiple processes, runs intermittently with an on-line spare, and causes no lost production
8	Impacts a single process, runs intermittently or continuous with an on-line spare, and causes no lost production
9	Minor or no impact on safety, product, or cost

Alternative View 2 of “Criticality”: “Distance” From Core “Value Added” Functions

Code	Description
1	Assets required for conducting “value stream” functions that produce the core “unit of value”
2	Assets required to ensure that “revenue producing” assets are powered or controlled
3	Assets required for order fulfillment functions such as sales orders, production planning, shipping, and accounting
4	Assets required for other core production or service functions such as material handling or warehousing
5	Non-revenue producing assets required for protecting revenue-producing assets from inoperable conditions
6	Non-revenue producing assets required for conducting supporting business functions
7	Non-revenue producing assets that impact quality of life

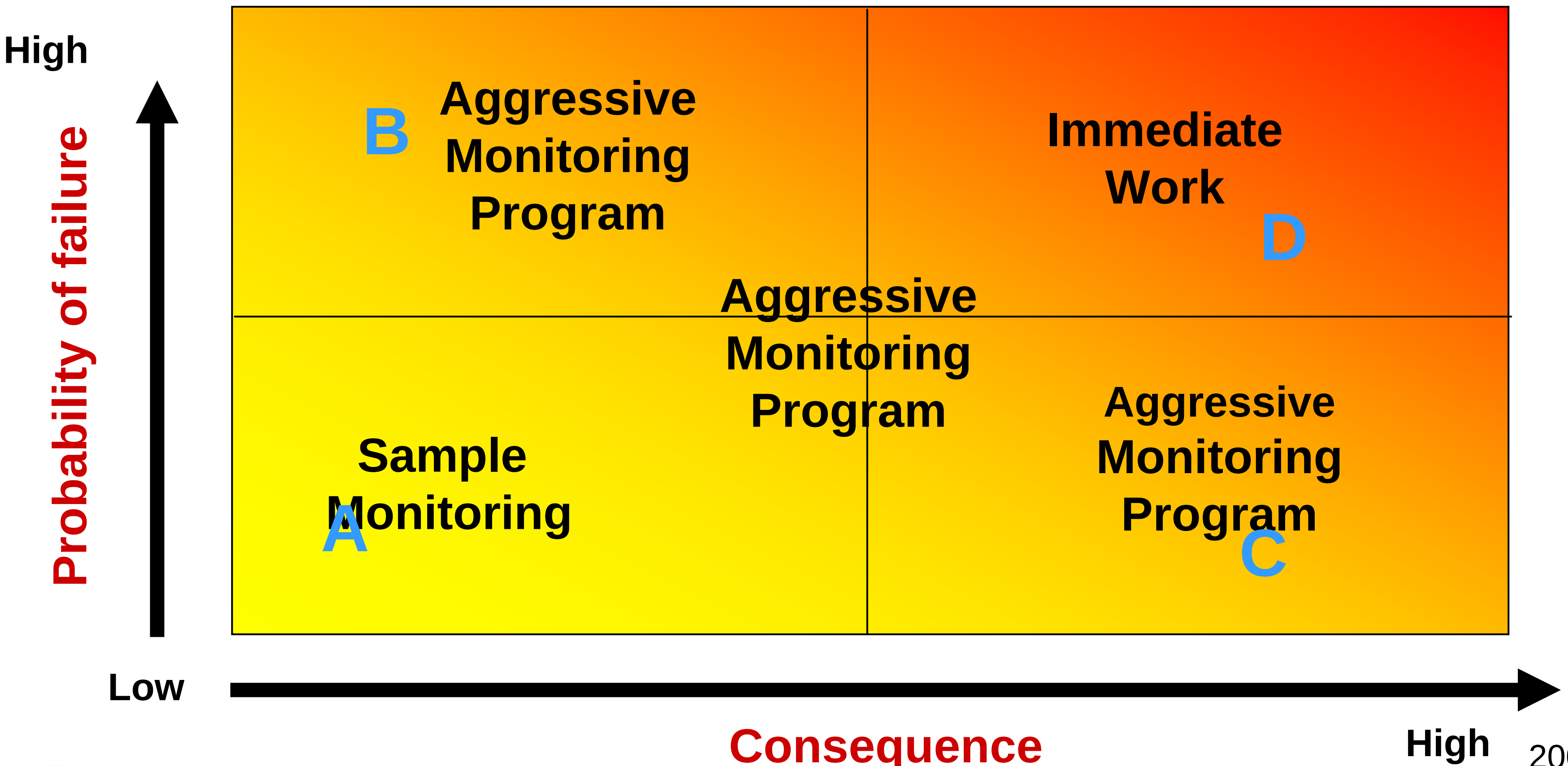
Determining “Significant” Failures: The Risk – Consequence Trade-off

- What is the likelihood of failure ? (risk)
- What is the cost of failure? (consequence)



Failure Risk/Consequence Drives Work Program

Failure Risk/Consequence Drives Work Program



The Risk (Criticality) Metric

Current Risk Cost	=	Costs of the Consequences Of Failure	X	Probability Of Failure (PoF)
⇩		⇩		⇩
Business Risk Exposure (BRE)		Consequence Of Failure (CoF)		Related to Condition, Reliability & Redundancy

$$BRE = CoF \times PoF$$

BRE* 1 - Simple Approach

* Business Risk Exposure

PoF / Likelihood	1	2	3
3	3	6	9
2	2	4	6
1	1	2	3

High

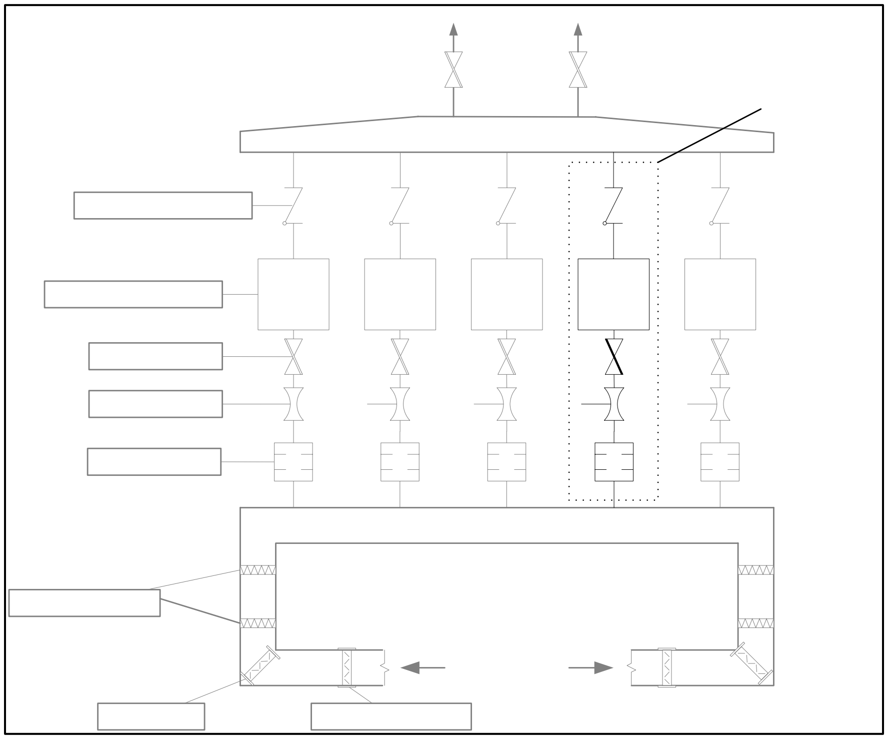
PoF / Likelihood

Low

High

CoF / Consequence of Failure

The Impact of Redundancy On The Risk Metric



Significantly reduces the risk metric!

(Risk = PoF X CoF x R)

Where:
PoF = Probability of Failure
CoF = Consequence of Failure
R = Redundancy Factor

See Detailed Schematic c
4 System Below

Air Discharge Header

Check Valve

1 25,000 CFM

2 40,000 CFM

3 40,000 CFM

4 40,000 CFM

5 25,000 CFM

Management Engineering Environment GHD Clients People Performance

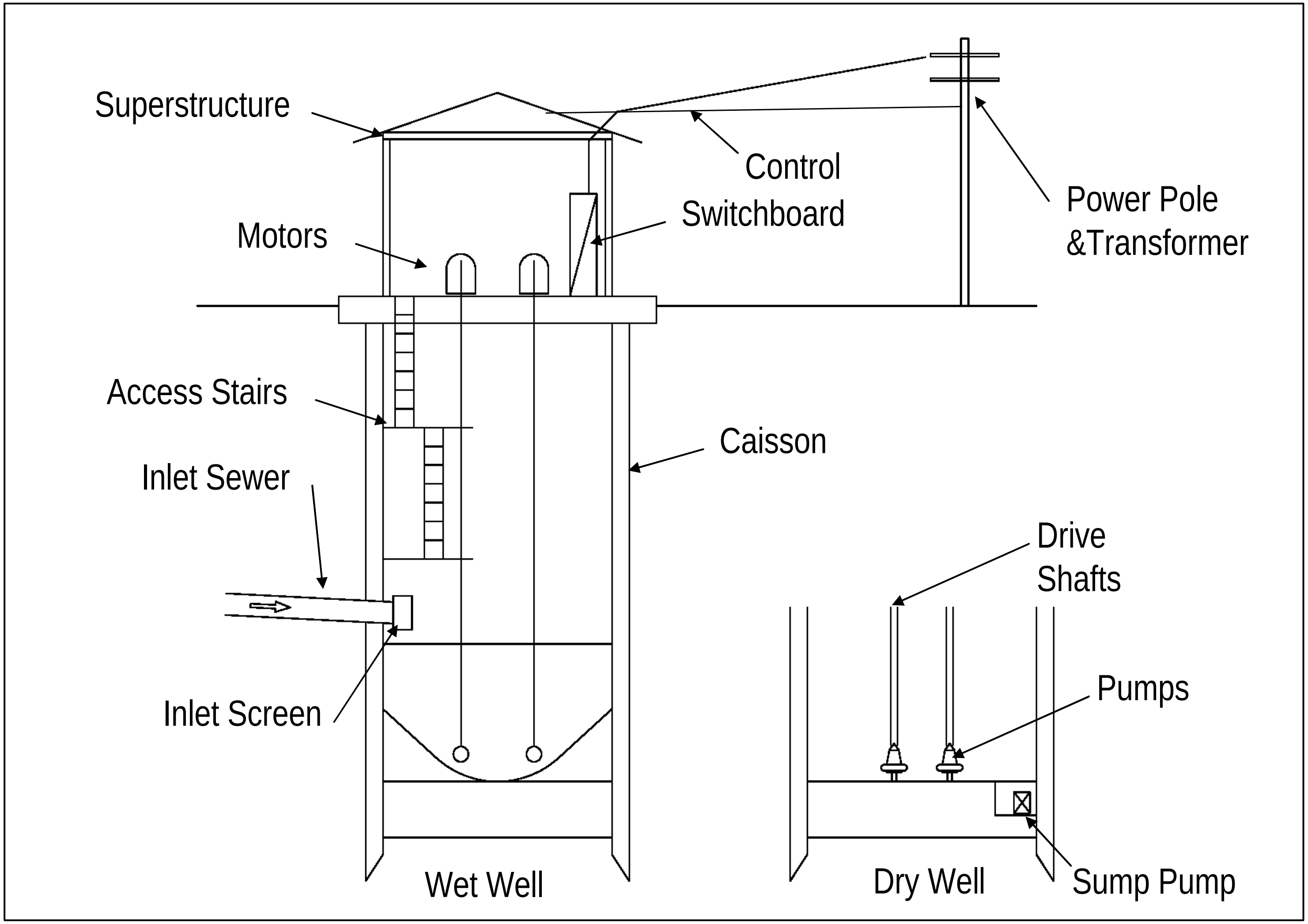
Weighting Redundancy

Don't Forget Redundancy!	
Level of Redundancy	**Reduce PoF by:**
50% Backup	50%
100% Backup	90%
200% Secondary Backup	98%

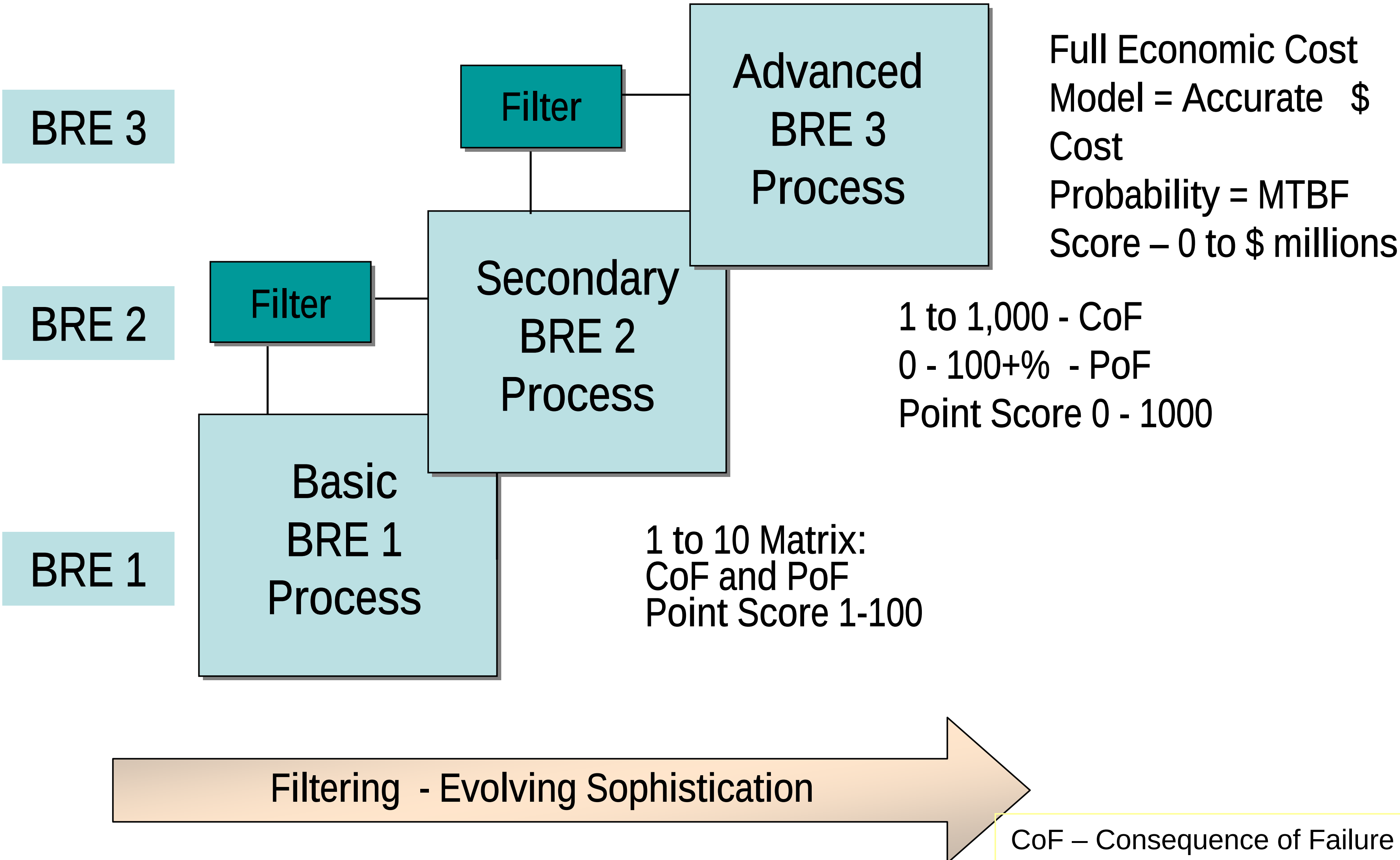
These weights are set considering the operating circumstances where possible:

- “True redundancy” (peak versus average)
- Age and condition of equipment
- Nature of operating environment
- Nature of failure modes (evident, hidden, random)

Does Tom Have Redundancy? If So, How Much?



Step by Step BRE Methodology



CoF – Consequence of Failure
PoF – Potential of Failure
BRE- Business Risk Exposure

Level 1 - Simple

Risk Rating = Probability X Consequence

ASSET No.	PROBAB.	CONSEQ.	RISK RATING
1	.60	4	2.4
2	.70	2	1.4
3	.40	5	2.0
4	.68	10	6.8 *
5	.95	7	6.7 *
6	.10	10	1.0

*** THESE REQUIRE FURTHER INVESTIGATION**

Level 2 – Intermediate

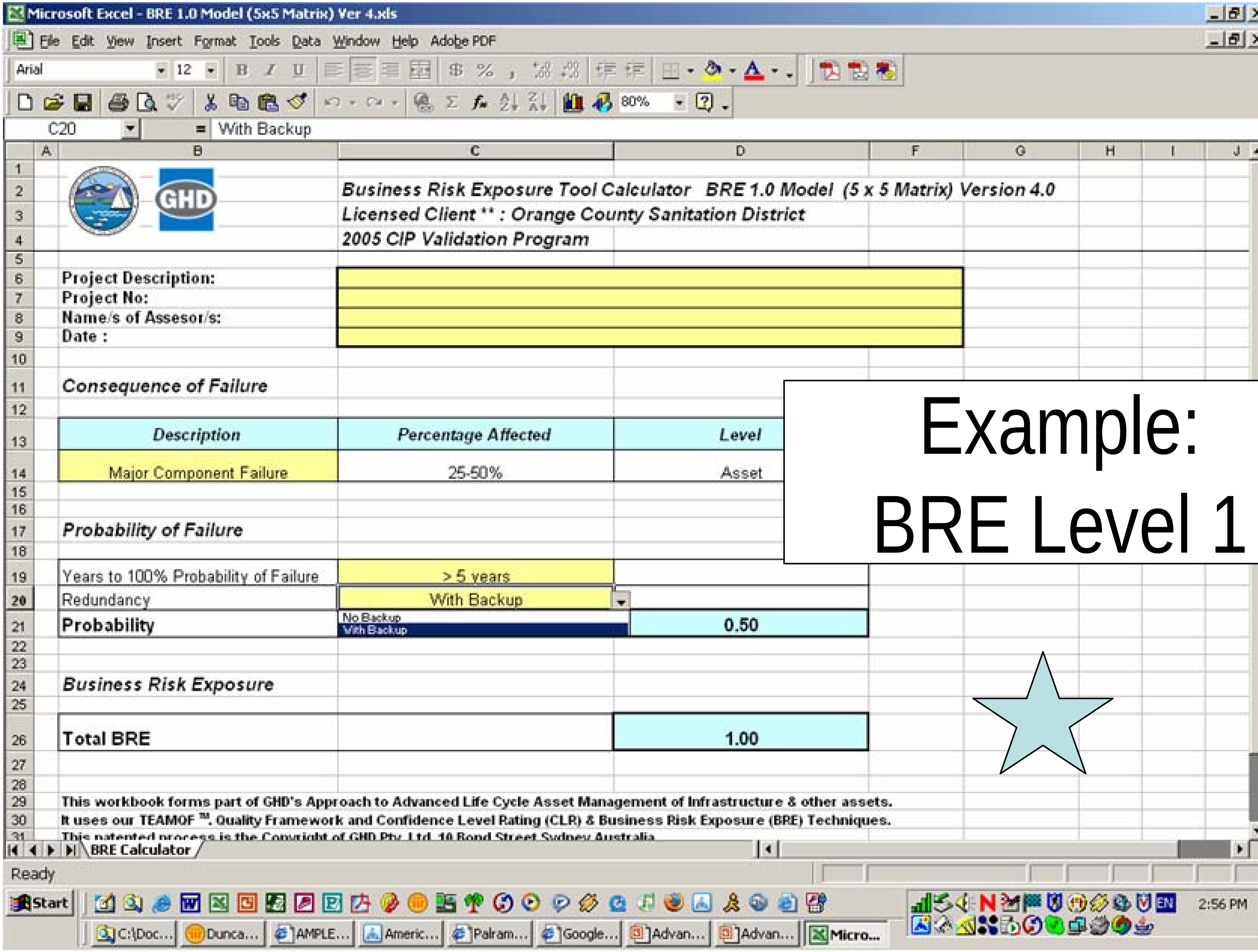
Multiple Elements

ENHANCED FMECA ANALYSIS TECHNIQUES

ELEMENT	RATING	WEIGHTING	MAX. SCORE
Safety	1 - 5	10	50
Environment	1 - 5	6	30
Functionality	1 - 5	5	25
Cost	1 - 5	8	40
			145

Example: Risk/Consequence Table

LIKELIHOOD	CONSEQUENCES					
	1	2	3	4	5	6
Very Low	L	L	L	L	M	M
Low	L	L	L	M	M	S
Moderate	L	L	M	M	S	S
Quite likely	L	M	M	S	S	H
High	M	M	S	S	H	H
Very High	M	S	S	H	H	H
Almost Certain	S	S	H	H	H	H



Example: BRE Level 1

Microsoft Excel - BRE 2 Model 1.xls

Orange County Sanitation District

Business Risk Exposure *BRE 2 Model 1*

Project Description:
Project No:
Date:
Name of Assessor:

Consequences of Failure	*Rating Column*	*Weighting*	*C of F*
Environmental Impacts	100 - Extreme damage to Ecosystem	10	1000
Repair Cost	120 - >$2 000 000	10	1200
Loss of Service	120 - >$100 000	10	1200
Time off Supply	30 - 6 Months to One Year	10	300
Area off Supply	90 - >200 Properties	5	450
Public Image	20 - State News	10	200
Property Damage	30 - > $200 000	5	150
System Disturbance	1 - Single Crew for 1 hour	20	20
Production Loss	150 - > $100 000	12	1800
Potential Injury or Fatality	100 - Single Fatality	8	800
Total		**100**	
Total Consequence of Failure			**7120**

Probability of Failure

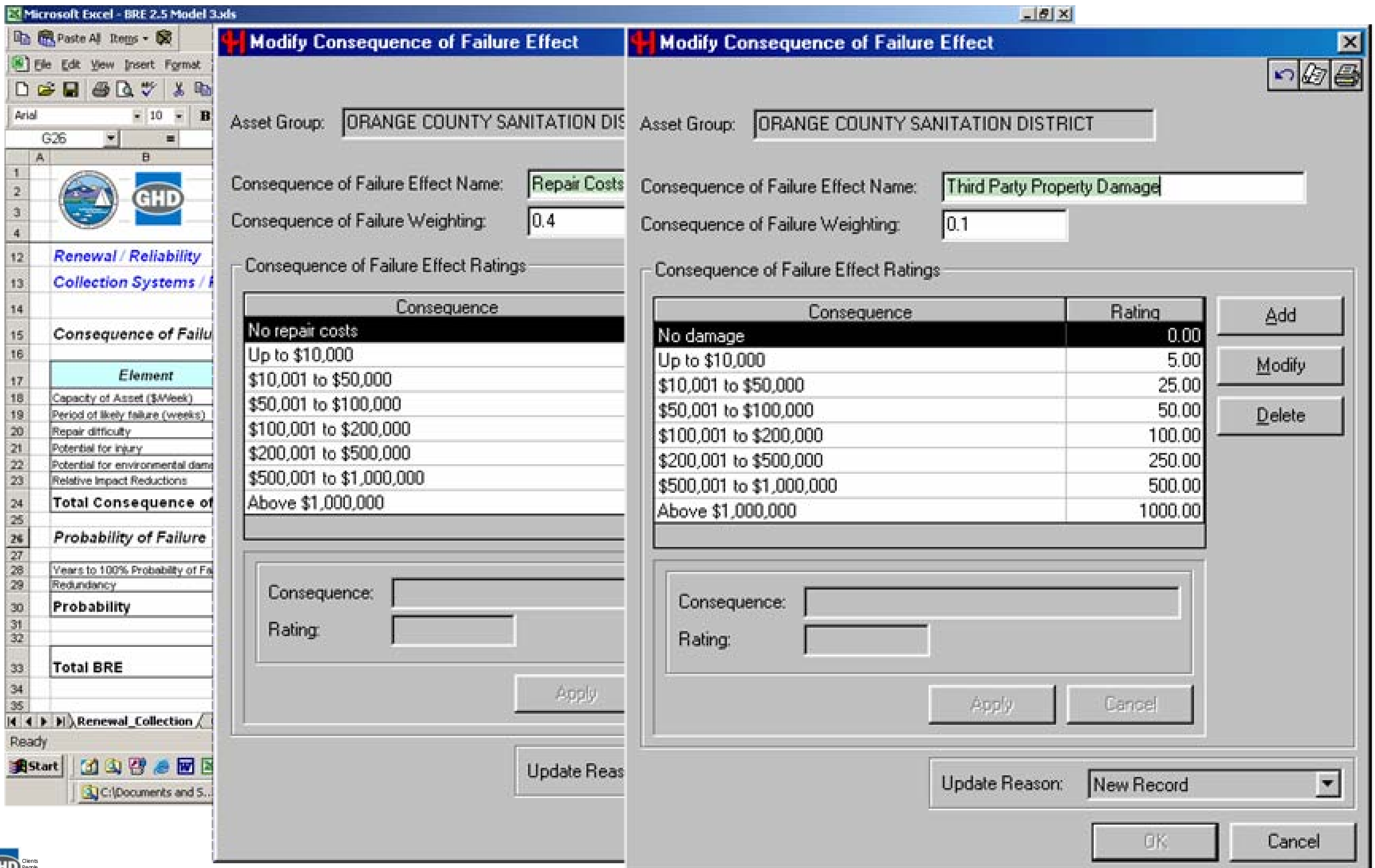
Years to 100% Probability of Failure	**3 years**
Redundancy	**50% Backup**
Probability	**18.00%**
Total BRE	**1290**

Example:
BRE Level 2

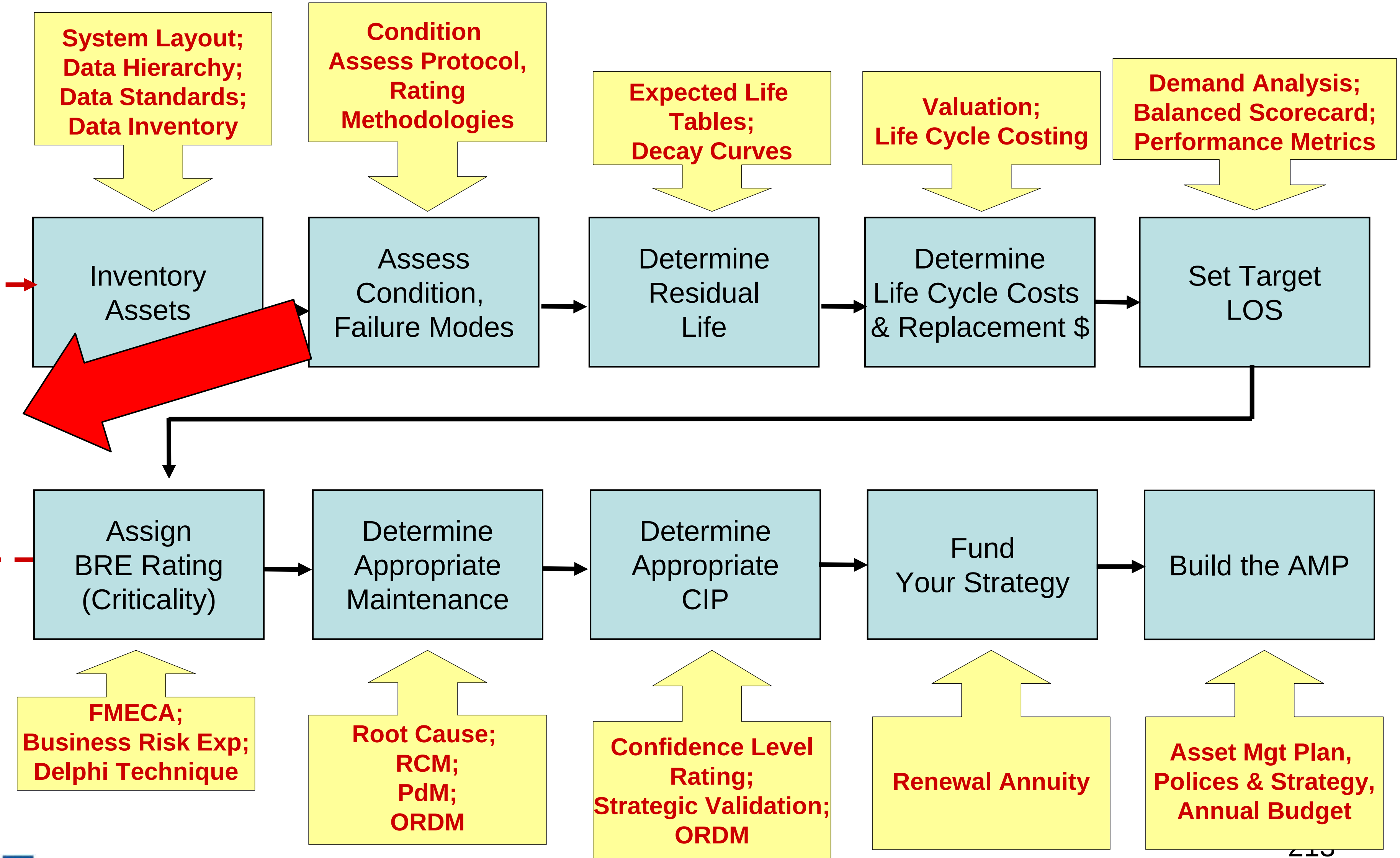
BRE 2 Model 1 / Sheet1

Ready

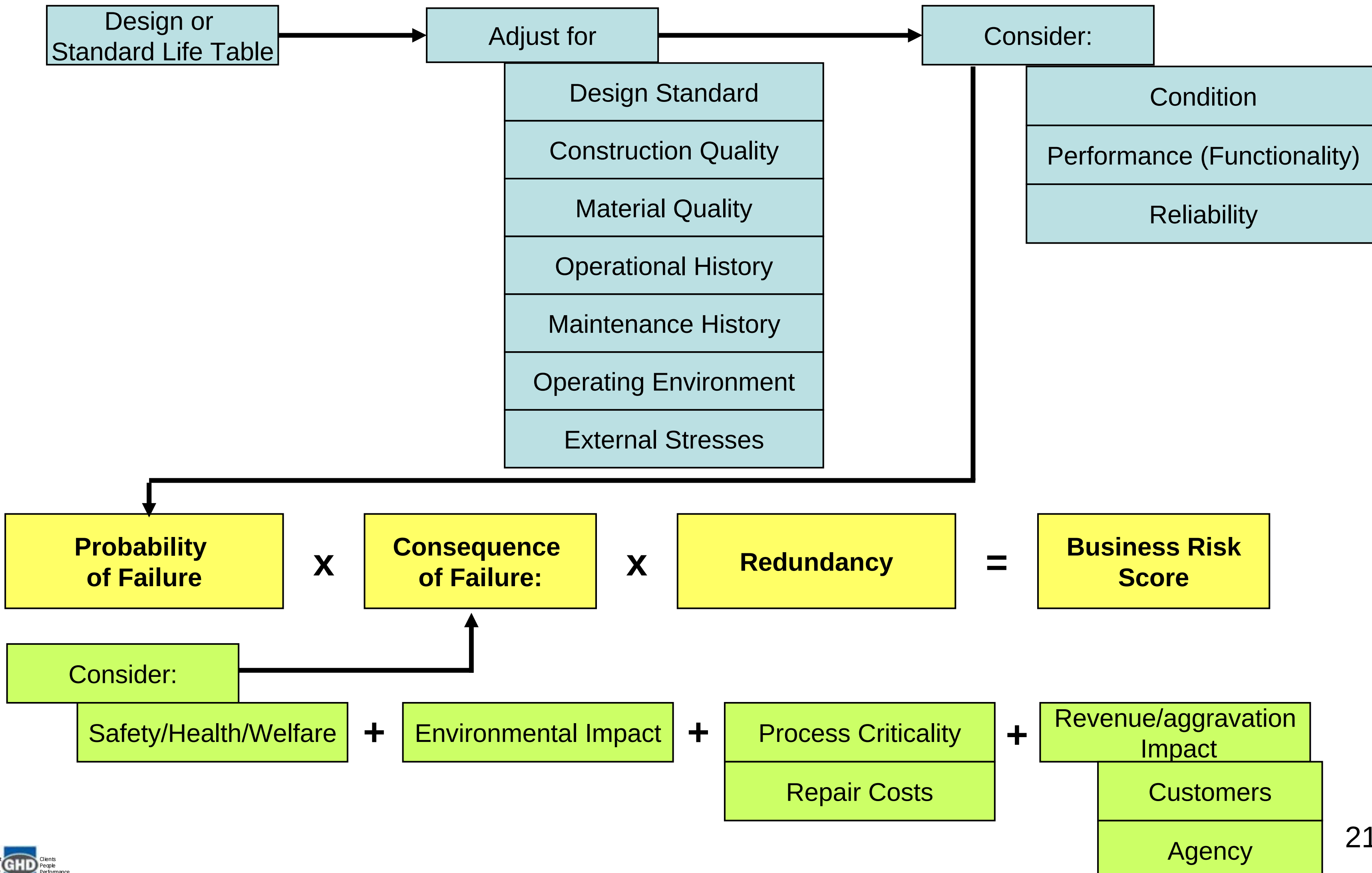
Level 3 – Advanced
Full Economic Cost Model



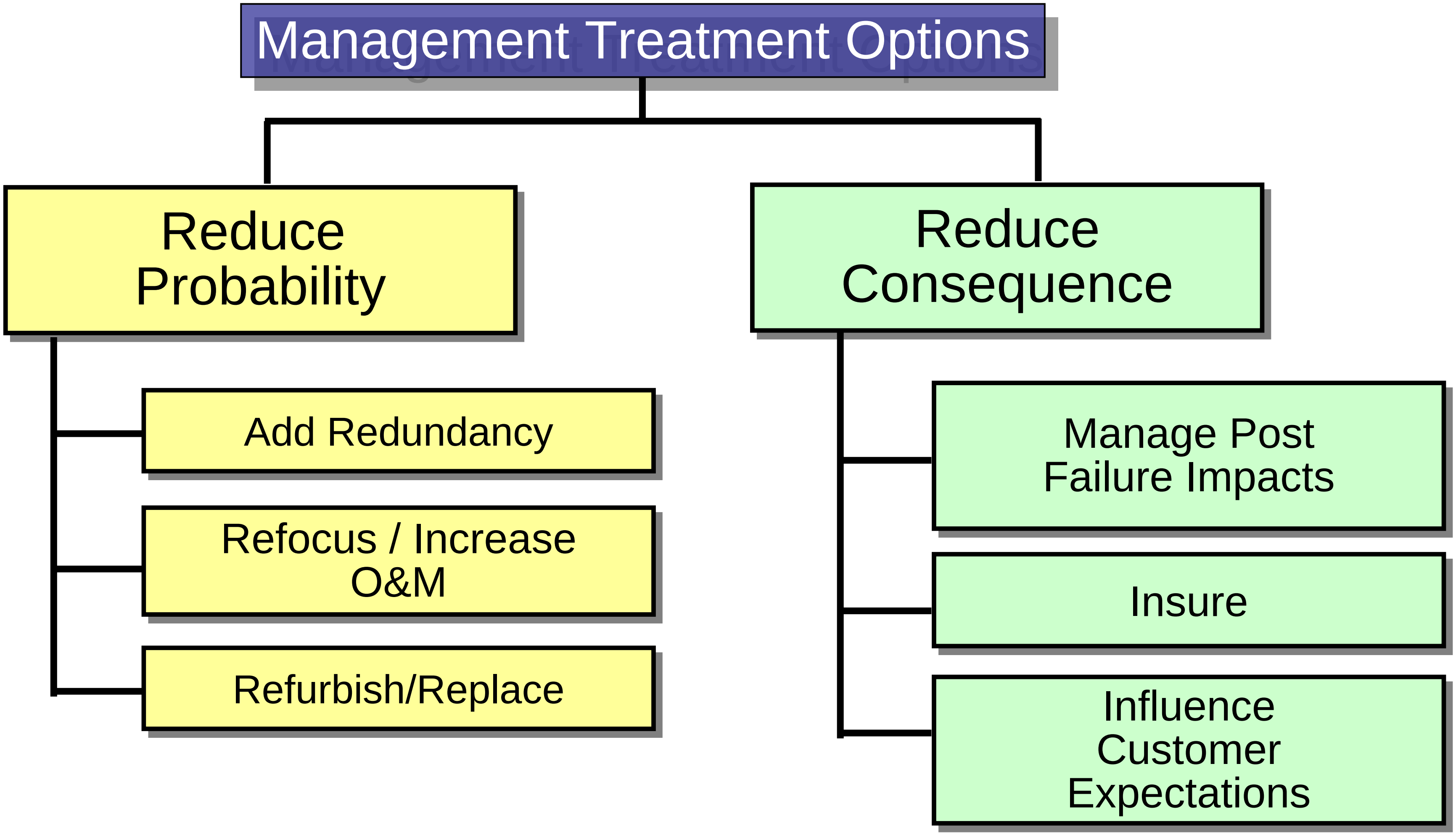
Modifying the 10 Step Process



Putting It All Together: Calculating Business Risk



Managing Risk: Risk Reduction Options



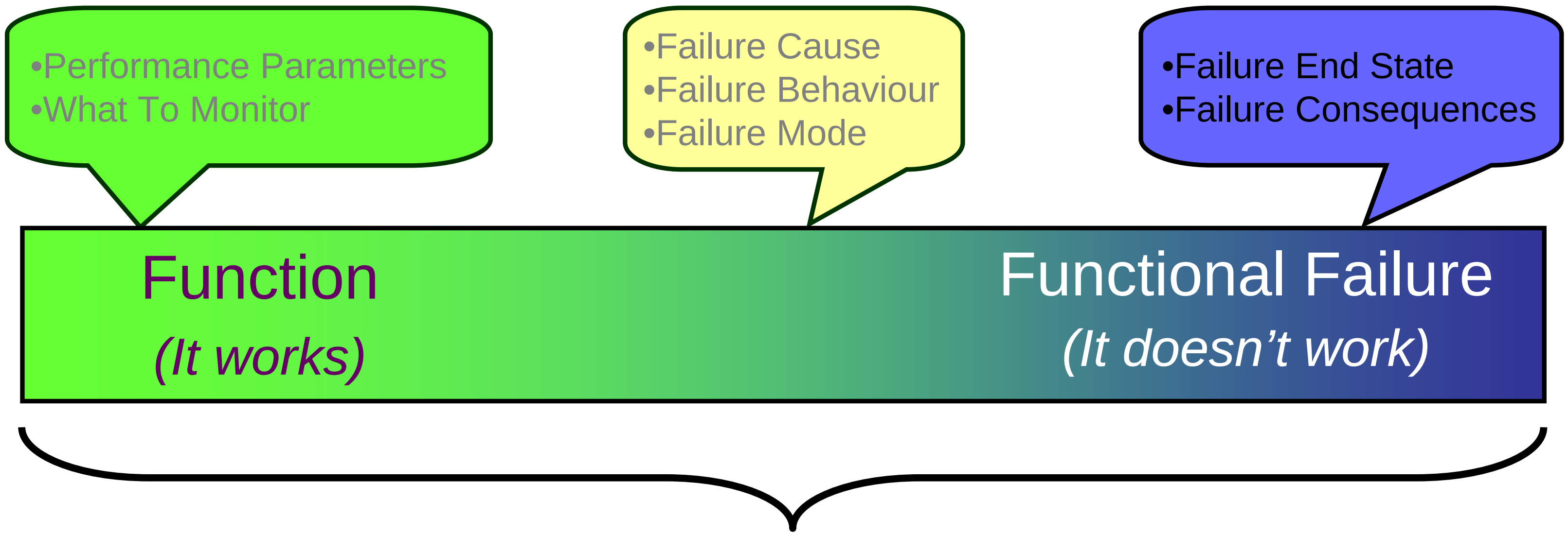
Some Failures Will Still Happen

Educate Our Customers To Expect Acceptable Or Unavoidable Failures

What Caused the Jones Street Lift Station to Fail?

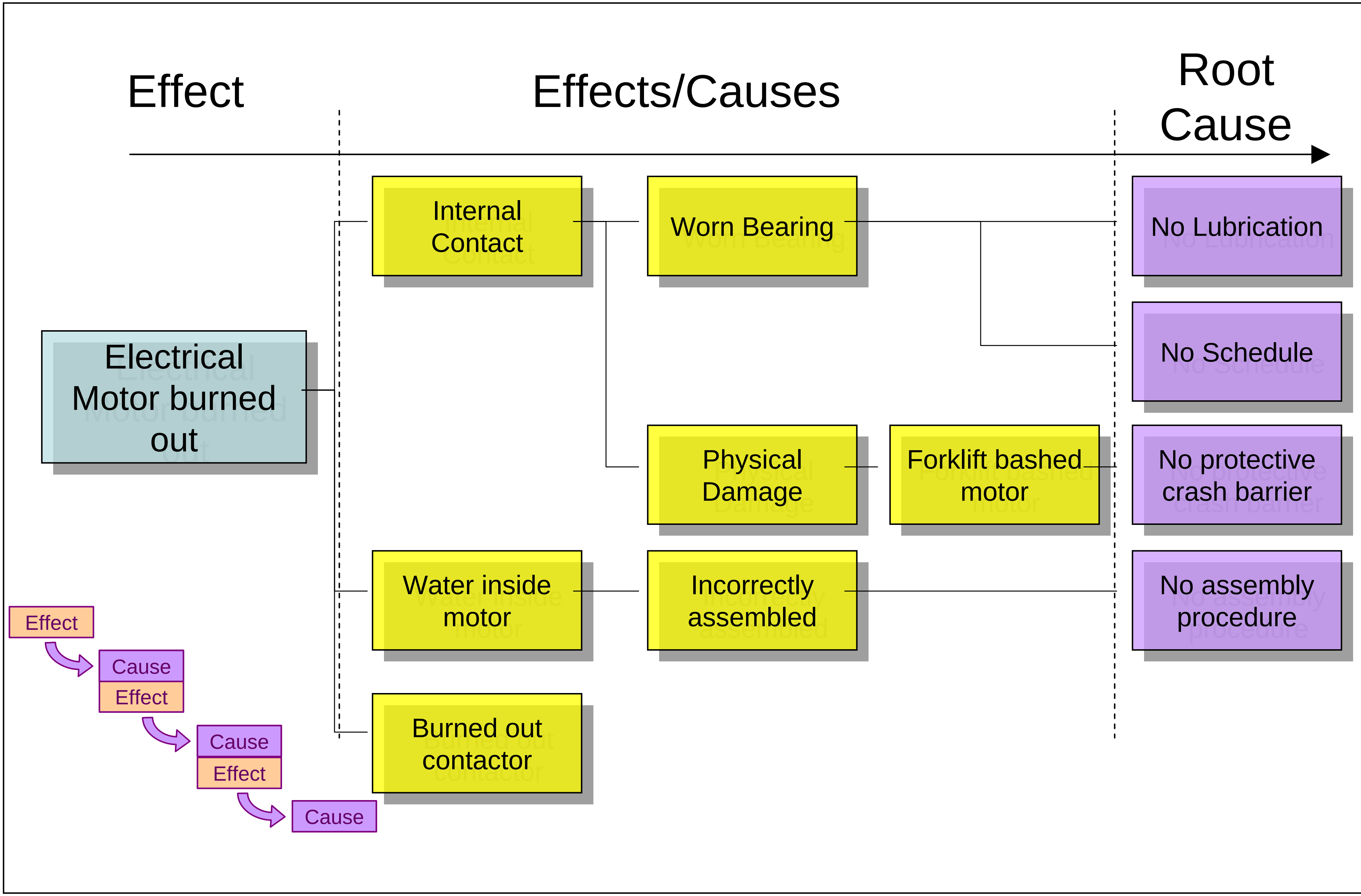
- Truck hits pole and causes power failure
- Don’t really know

Failure Analysis



Function	Functional Failure	Failure Cause	Failure Mode	Failure Behaviour	Failure Consequences
Defined by Performance Standards	End state or potential end state, Evidence, what you see	Contributing Causes and Root Cause, reason why failure occurred	Mechanism of failure	Evident, Hidden, Random, PF Interval	Cost, Safety, Environmental

Cause and Effect Diagrams



June’s Incident Report Notes

19:35 - Entered superstructure to shut off power breakers before power-up. The main breaker had been thrown. No immediate clue as to what caused it to trigger. No sign of arcing or flash explosion around the box. That means neither Motor/pump 1 or Motor/pump 2 could run. No wonder the overflow. Why both down?

20:25 - Power temporarily restored by Costly Electric & Illumination; will return in am to install permanent pole. (Shouldn’t we ask them to move it back from the road?)

20:30 - Mac and I turned on main breaker to Motor 1. Immediately heard loud screeching. Seems to be from Motor 1. Immediately shut main down. Turned off breaker to Motor 1. Turned on main. Good news - Motor 2 ran fine. No unusual noise. Nice to have lights. Wonder if coffee pot works!

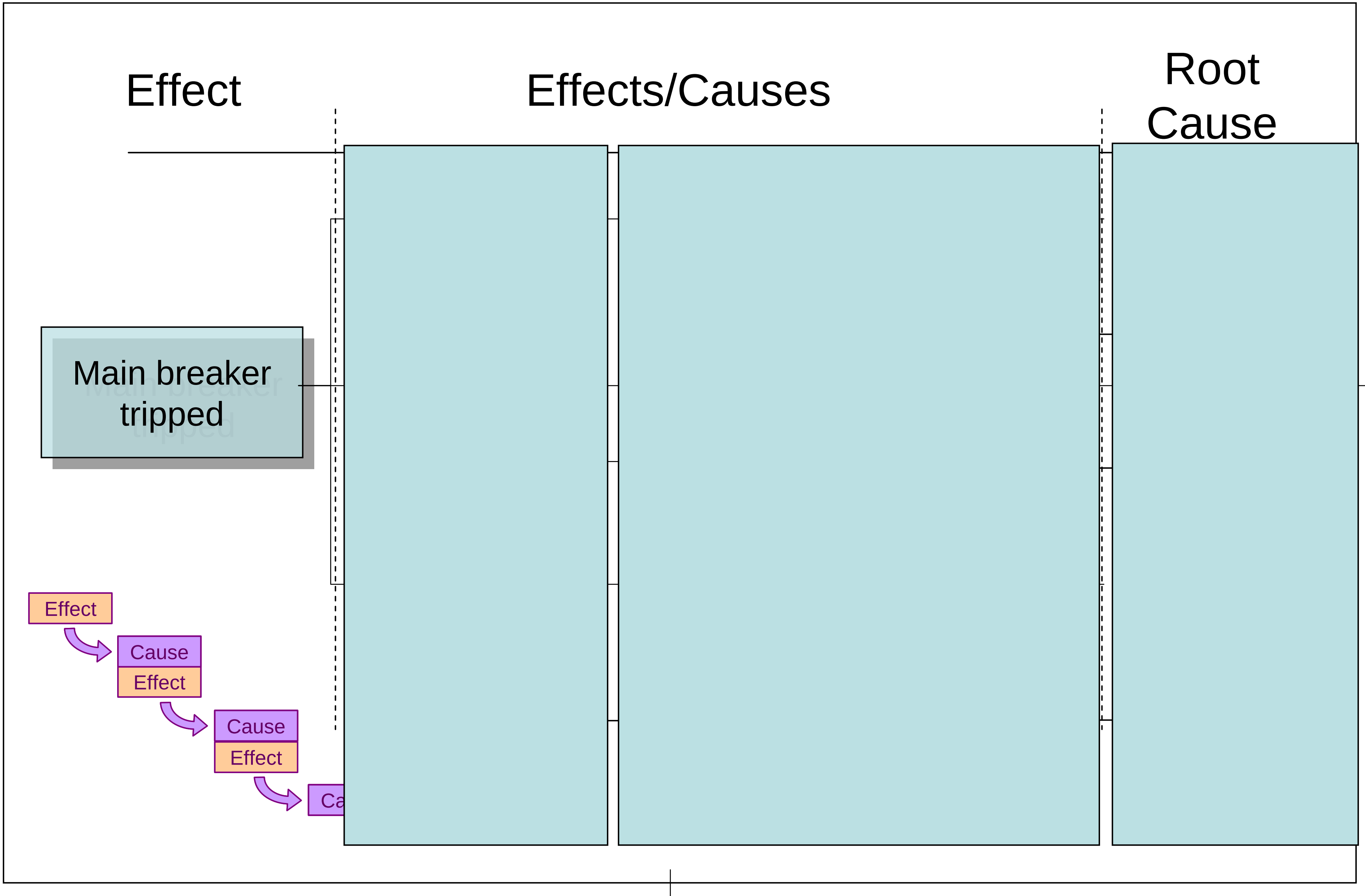
20:40 - Noted that motor mounts on Motor 1 appear loose - black skid marks up to ½ inch from front feet; back shows movement but not as bad.

20:45 - I entered wet well and dry well with Motor 2 running. Mac stayed top. Noted that the two shaft guides on the wall for Motor/pump 1 was completely loose, one side pull off wall. Bolts pulled clear from wall too. Noticed substantial play in pump shaft at the coupler to the shaft. Way too much play here. See photos.

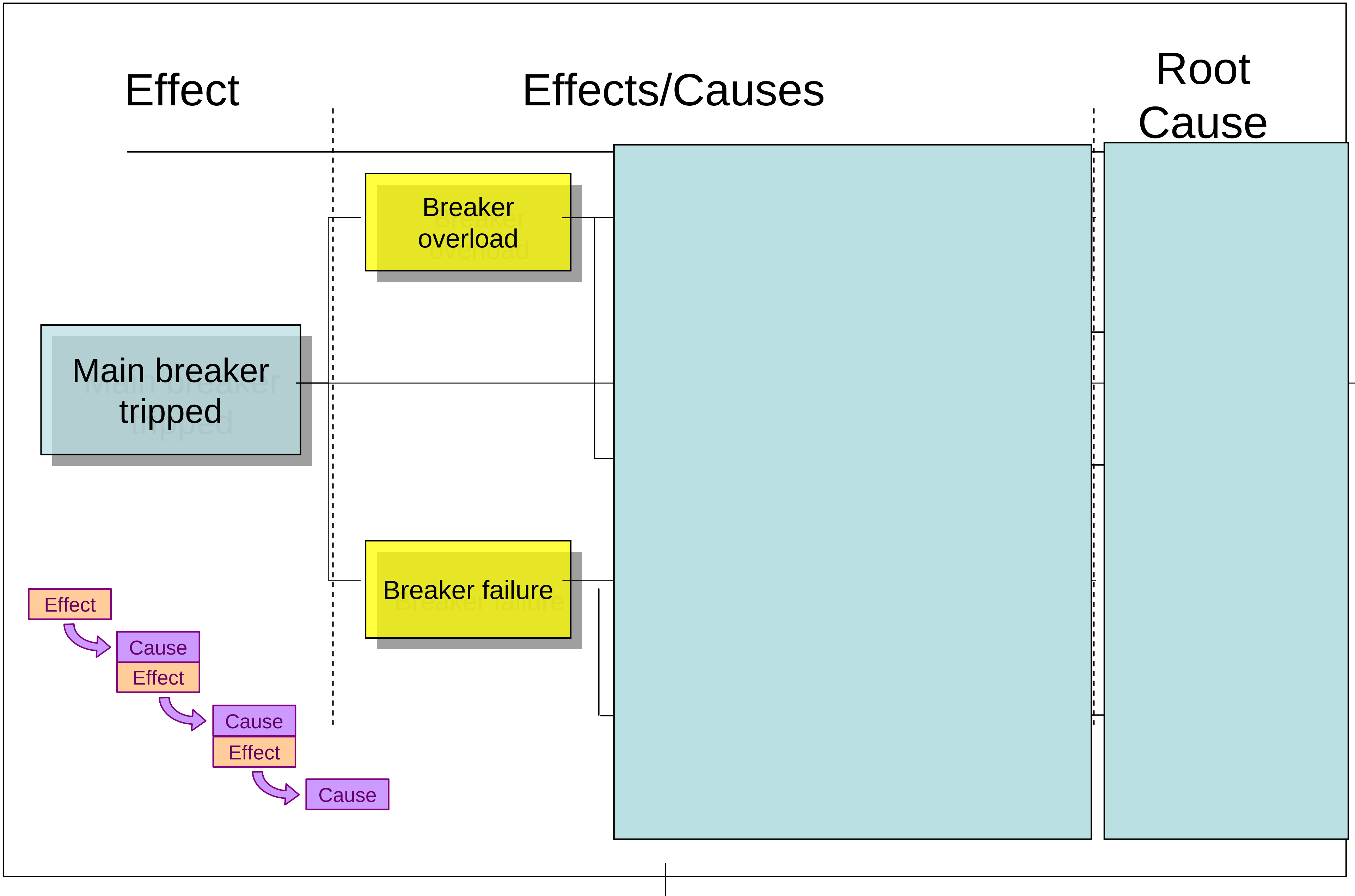
05:15 My guess at this point - Looks like vibration worked the shaft guides loose, increasing strain on the motor, working the motor loose, which strained bearings to point of break down.

05:30 Sent crews home with Motor/pump 2 running alone. What to do with Motor/pump 1? Repair? Refurbish? Replace? Will discuss with you after I get some shut eye.

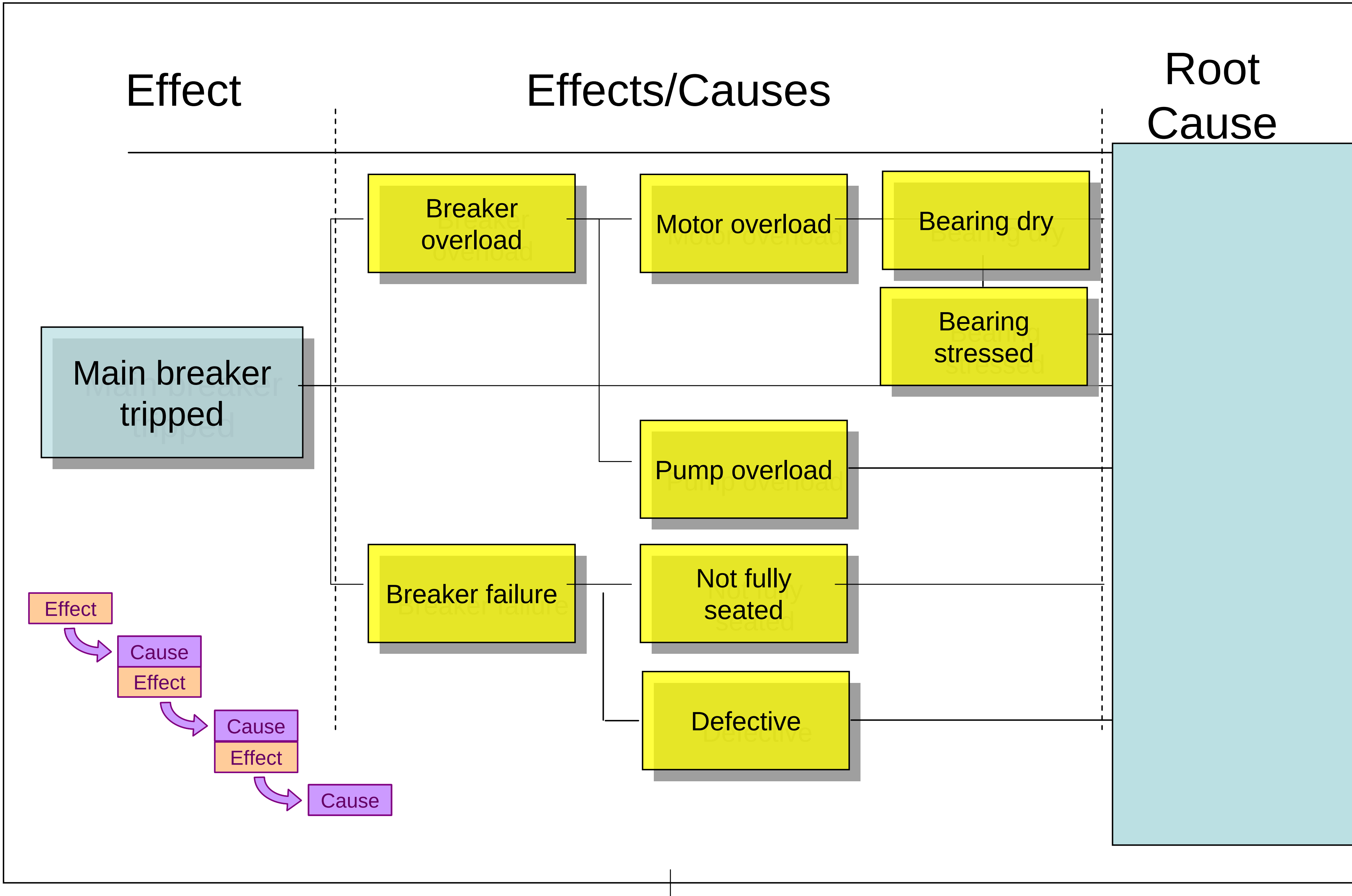
Cause and Effect Diagrams



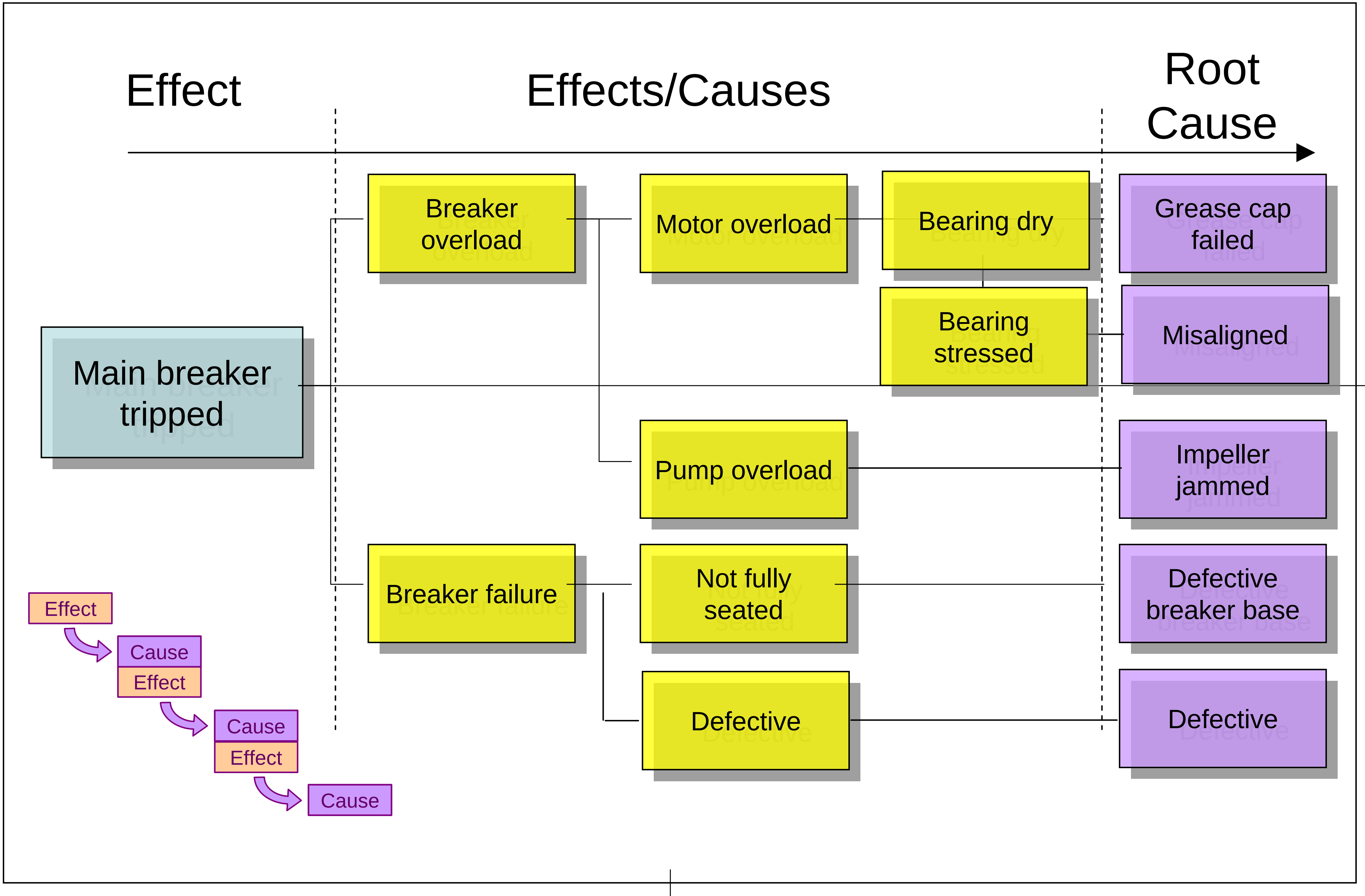
Cause and Effect Diagrams



Cause and Effect Diagrams



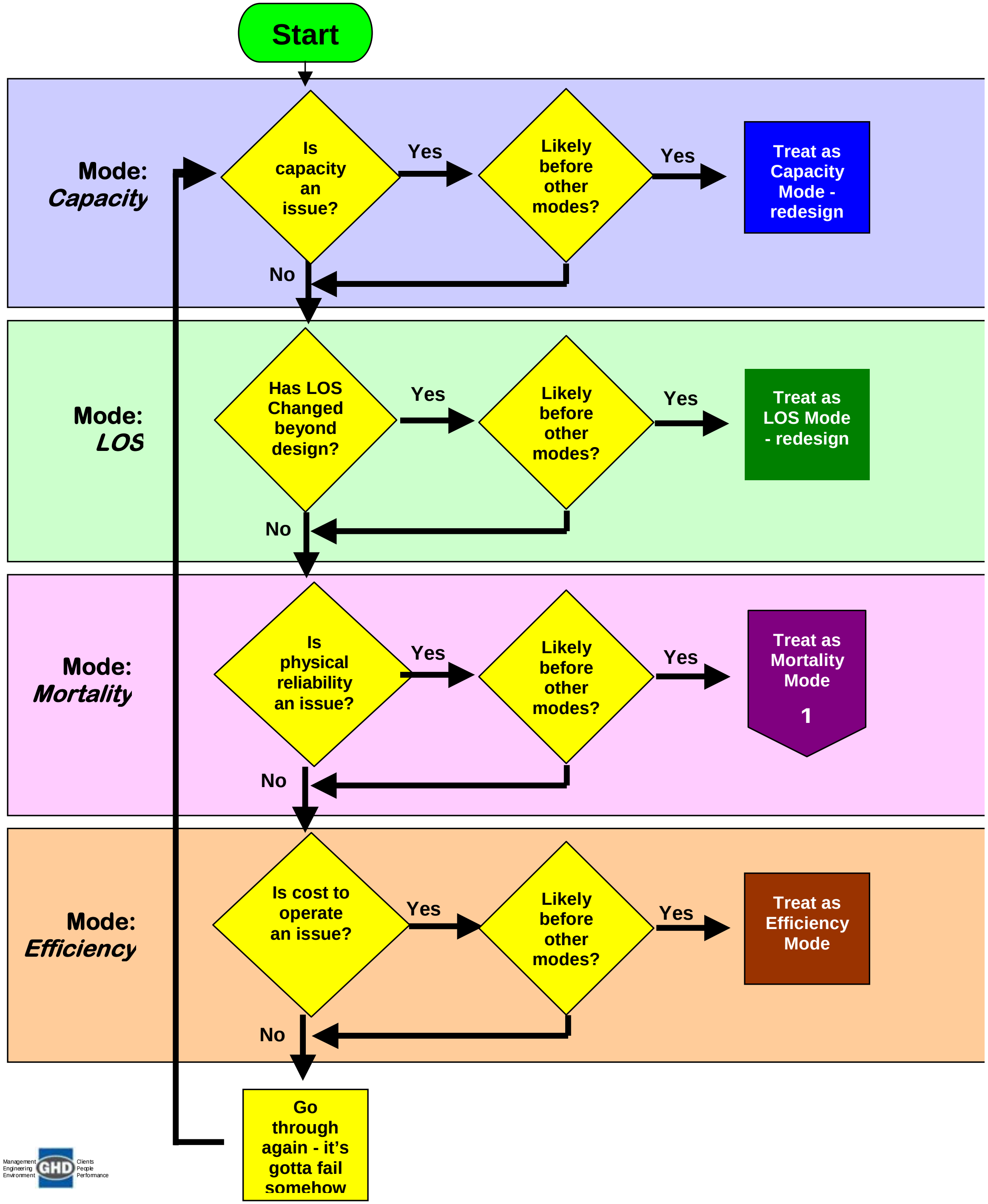
Cause and Effect Diagrams



Which Major Failure Modes Are At Work?

Mode	Definition	Tactical Aspects	Strategic Management Strategy
1. Capacity	Volume of demand exceeds design capacity	Growth, system expansion	Redesign
2. LOS	Functional requirements exceed design capability	Codes: NPDES, CSOs, SSOs, OSHA, noise, odor, life safety; Service, etc	Redesign
3. Mortality	Consumption of asset reduces performance below an acceptable minimum level	Physical deterioration due to age, usage (including operator error), nature	O&M, Renewal
4. Efficiency	Performs ok, but cost of operation exceeds that of alternatives	“Pay-back” period	Replace

The “Primary Failure Mode” Gives Insight Into Setting the Probability of Failure



Exercise Number 3

Help Tom develop an understanding of the criticality (BRE) of the components of the pump station

Using the data provided, determine:

- The consequence of failure using the 1 to 10 score table in the exercise spreadsheet
- Apply these to all the components you have in your asset register

Exercise Number 3

- The probability of failure will be calculated by the spreadsheet using the residual life (but in future you need to use real data)
- Have a look at the BREs. Are they what you expected ?
- What is the total BRE for the pump station?

BRE – Business Risk Exposure

Sheet C on the exercise spreadsheet

Probability of Failure

% of Effective Life Consumed	PoF Rating
0%	**1**
10%	**2**
20%	**3**
30%	**4**
40%	**5**
50%	**6**
60%	**7**
70%	**8**
80%	**9**
90%	**10**

Don't Forget Redundancy??

Level of Redundancy	Reduce PoF by:
50% Backup	50%
100% Backup	90%
200% Secondary Backup	98%

This is calculated based on condition rating

Key Lessons Learned

- ⇨ BRE is the heart of all good Advanced AM.
- ⇨ It helps us make better decisions by far …
- ⇨ BRE comes in different levels of sophistication.
- ⇨ You can start very easily – as shown.
- ⇨ PoF data is hard to get and is individual asset related.
- ⇨ So start completing your work orders now.

BRE – Business Risk Exposure
PoF – Potential of Failure

AGENDA

<u>*Day 1*</u>

- *Welcome, Introductions & Housekeeping Details*
- *“Storyline” Introduction, Background And Context*
- *Overview Of Fundamental Concepts & Core Practices*
- *The Storyline: Tom’s Really Bad Day*
- *Core Question 1: What Is The Current State Of My Assets?*
- *Core Question 2: What Is My Required “Sustainable” Level Of Service?*
- *Core Question 3: Which Assets Are Critical To Sustained Performance?*
- *Review of Key Slides; Discussion /Q & A*

Strategic Business Risk

"A business risk" is the threat that an event, <u>action or inaction</u> will adversely affect an organization's ability to achieve its business objectives and execute its strategies successfully.

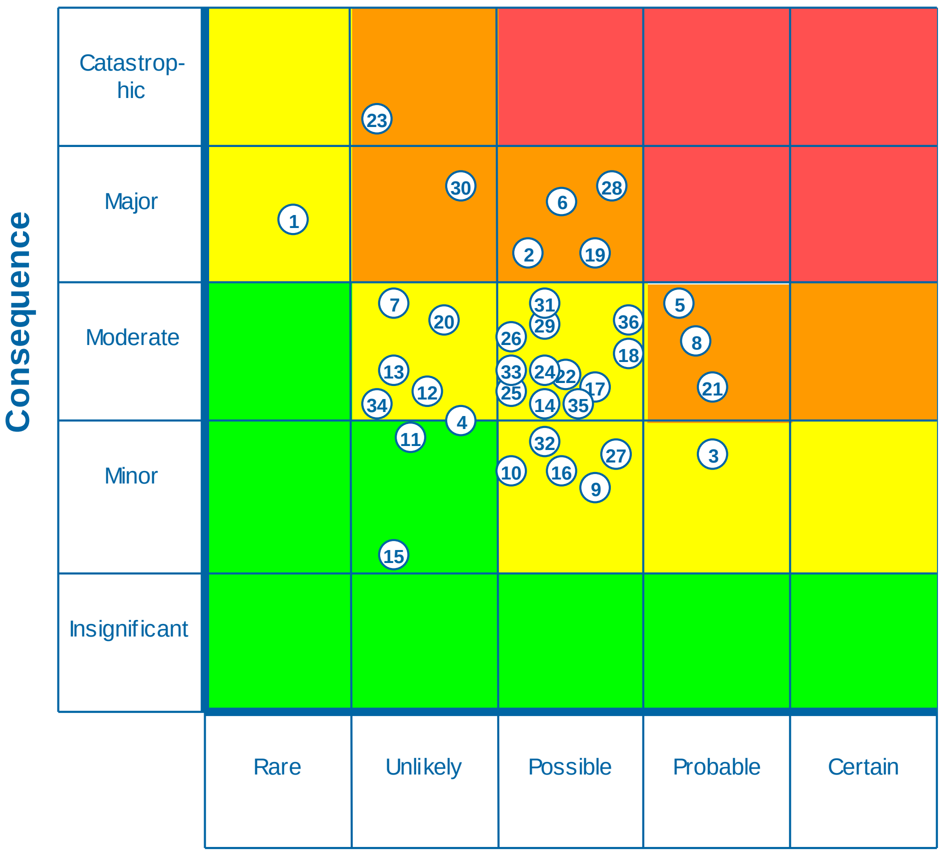
Management of these risks has the twofold advantage of both avoiding and minimizing the risk itself, and enabling informed business decision-making based on an understanding of where the business vulnerabilities lie.

Mapping Organizational Risk

1 Terrorist attack on OCSD asset (e.g. treatment plant)
2 Regional power outage (up to 24 hours)
3 Safety incident on OCSD project
4 Internal security breach of IT systems
5 Increase in regulatory requirements
6 Finding places to put our biosolids
7 Potential loss of property tax revenue
8 Internal labor unrest at OCSD
9 Consultants ability to meet stakeholders expectations
10 Level of service change for environmental stewardship (constituents of concern)
11 Loss of public confidence in OCSD ability to perform core services
12 Exceedance of pollutants of concerns in groundwater related to GWRS
13 Internal business fraud (e.g. malfeasance)
14 Non compliance by OCSD that result in fines by regulators and legal activities by NGO's
15 Lack of incentives for early retirement of ageing staff that perform physical activities
16 Poor two way communications across OCSD levels
17 Lack of a leadership model in EMT and management level
18 Changing technology vs. CIP decisions
19 Board not supporting the funding required to support CIP/O&M (Full Cost Pricing)
20 Ability to accurately forecast growth of county
21 Loss of Board institutional knowledge
22 Not sustaining effective plant operations during construction
23 Disasters that destroy collection system or plant
24 Inability to appropriately fund staff at required technical strength
25 Inability to balance strategic initiatives that support GWRS (Groundwater Replenishment System) with plant operations
26 Emergency (operations level) communication among response teams and management for emergencies
27 Lack of alignment of organizational structure with requirements for strategic initiatives
28 Unable to put into effect funding agreement for SARI (Santa Ana River Interceptor)
29 Unable to negotiate new operating agreement with SAWPA (Santa Ana Watershed Project Authority)
30 Public ceases support for GWRS after investment is in place
31 Inability to meet new air emission standards for generating facility
32 Inability to balance impacts on neighbors with desire by public to reduce cost
33 Cost to meet odor and air emissions standards from facilities
34 Privatization of OCSD
35 Recruiting and retention of staff in face of local cost of living
36 Lack of succession planning at OCSD

Mapping Organizational Risk

Sanitation Utility Risk Profile



Likelihood

Schematic represents allocation of risk rather than absolute values

Critical Risks: None categorized as Critical

High Risks:

2 Regional power outage (up to 24 hours)
5 Increase in regulatory requirements
6 Finding places to put our biosolids
8 Internal labor unrest
9 Consultants ability to meet stakeholders expectations
19 Board not supporting the funding required to support CIP/O&M (Full Cost Pricing)
21 Loss of Board institutional knowledge
23 Disasters that destroy collection system or plant
28 Unable to put into effective funding agreement with key customer
30 Public ceases support for potable water after investment is in place

Medium Risks:

1 Terrorist attack on assetS (e.g. treatment plant)
3 Safety incident on major projects
7 Potential loss of property tax revenue
10 Level of service change for environmental stewardship (constituents of concern)
12 Exceedance of pollutants of concerns in groundwater
13 Internal business fraud (e.g. malfeasance)
14 Non compliance that result in fines by regulators and legal activities by NGO's
16 Poor two way communications across department levels
17 Lack of a leadership model in EMT and management level
18 Changing technology vs. CIP decisions
20 Ability to accurately forecast growth of county
22 Not sustaining effective plant operations during construction
24 Inability to appropriately fund staff at required technical strength
25 Inability to balance strategic initiatives that support groundwater replenishment with plant operations
26 Emergency (operations level) communication among response teams and management for emergencies
27 Lack of alignment of organizational structure with requirements for strategic initiatives
29 Unable to negotiate new operating agreement with key customers
31 Inability to meet new air emission standards
32 Inability to balance impacts on neighbors with desire by public to reduce cost
33 Cost to meet odor and air emissions standards from facilities
34 Privatization of organisation
35 Recruiting and retention of staff in face of local cost of living
36 Lack of succession planning

Low Risks:

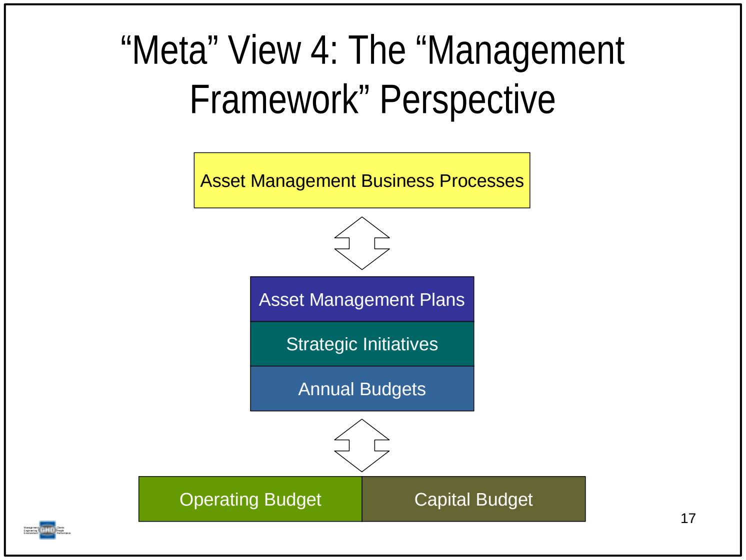
4 Internal security breach of IT systems
11 Loss of public confidence in organisation to perform core services
15 Lack of incentives for early retirement of ageing staff that perform physical activities

Management Engineering Environment GHD Clients People Performance

Draft Risk Register - Developed by OCSD Jan 30th, 2006 and Feb 6th, 2006

Risk Identification and Analysis									Plan		
#	Risk Issue	Causes and Notes	Potential Impact / Consequence	Current Mitigation Measures	Initial Risk			Proposed Mitigation Measures	By Whom	By When	Complete
					Consequence	Likelihood	Risk				
6	Finding places to put our biosolids	Potential ordinances against OCSD disposal of biosolids. Lack of availability of suitable disposal sites. Lack of on site disposal. Natural closure of transport routes. Saturation of market with biosolids.	Public health implications. Increased costs to source landfill sites. Limitations for onsite storage at OCSD. Violation of permit.	OCSD Masterplan which covers on and off site actions. Specific section addressing monitoring the situation including regulations, politics etc. Existing multiyear contracts with different vendors. OCSD actively seeking new tactical options (e.g. composting). Active promotion in county uses of solids. Program inplace to seek and set up new technologies to identify alternatives for biosolids disposal.	Moderate	Possible	Medium	Influence state legislation to remove prohibitions on disposal. Seek federal pre-exemption. Support advanced technologies that reduces % of biosolids per unit input. Develop programs to reduce biosolids per unit input. Purchase own OCSD landfill site. Identify additional landfill sites in East California. Joint ventures with others for a regional facility.	Bob Ghirelli		
7	Potential loss of property tax revenue	Political decision regarding funding made at State level. State budget issues. Perception of self sufficiency at OCSD. Current revenue $100m per year from property tax.	Need to increase rates. Reduction in capital investment. Operating budget reduction.	New state legislations tructure that makes changes (reductions) more difficult.	Major	Possible	High	Increased vigilance in monitoring potential legislative action (lobbyist, trade groups), due to lead time required to react. OCSD need to proactively move away from Tax Revenue - to be determined.	Lorenzo Tyner		
8	Internal labor unrest at OCSD	Link to risk 4. Union demands. Completion of contract.	Work to rule. Staff shortages. Level of service impacted. Vandalism. Morale. Negative impact on recruitment. Interruption to supply of chemicals (storage under a week).	Labor contracts are negotiated and OCSD offers a competitive salary and benefits program. Turnover of staff currently at 3% per year. Labor management committee reviews organizational issues, collaborative issues/problem solving. Contract negotiations, covering 90% of staff, begin in 3rd quarter 2006 and will be completed by end of second quarter June 2007.	Moderate	Unlikely	Medium	Need to identify emerging issues that may effect OCSD labor e.g. medical retirement in order to develop suitable strategies ahead of time. Develop and implement a 'interest based bargaining program' - prior to contract negotiations for both parties to be better aligned. Development of a process to monitor issues that arise in the workplace. Development of a leadership program which will upskill leaders to deal with labor issues effectively (e.g. at manager and supervisor level) Development of a performance management scheme and succession planning. Apply organizational surveys to assess current status with local OCSD managers to administer results. OCSD to move away from defending the benefits to demonstrate the value in working for OCSD. NOTE the key issue is medical benefits.	Lisa Tomko?		

Review of Today's Key Slides



Core Questions

1. What is the current state of my assets?
- What do I own?
- Where is it?
- What condition is it in?
- What is its remaining useful life?
- What is its economic value?

2. What is my required sustained Level Of Service?
- What is the demand for my services by my stakeholders?
- What do regulators require?
- What is my actual performance?

3. Given my system, which assets are critical to sustained performance?
- How does it fail? How can it fail?
- What is the likelihood of failure?
- What does it cost to repair?
- What are the consequences of failure?

4. What are my best "minimum life-cycle-cost" CIP and O&M strategies?
- What alternative management options exist?
- Which are most feasible?

5. Given the above, what is my best long-term funding strategy?